Agar & Agar

Irritable bladder

5 gr Acid Sodium Phos-
phate between meals &

5 gr urotropine after
meals

DISEASES OF THE KIDNEYS,
URETERS AND BLADDER

Kidney and Bladder Stones from Authors' Collection and that of Dr. H. H. Young. For notes on their chemical composition, investigated by Dr. G. L. Gordon, of Vancouver, see Vol. II, p. 92.

DISEASES OF THE KIDNEYS, URETERS AND BLADDER

WITH SPECIAL REFERENCE TO THE DISEASES IN WOMEN

BY

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VOLUME I

WITH 628 ILLUSTRATIONS, FOR THE MOST PART BY MAX BRÖDEL

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TO

DOCTORS WILLIAM J. AND CHARLES H. MAYO,

CREATORS OF A SURGICAL ERA, WHOSE PERSONALITIES ARE ENSHRINED IN THE AFFECTIONS OF THOUSANDS OF THEIR COLLEAGUES AND FELLOW COUNTRYMEN, THESE VOLUMES ARE AFFECTIONATELY INSCRIBED BY THE WRITERS AND BY MANY OF THEIR CO-LABORERS, SOMETIME MEMBERS OF THE GYNECOLOGICAL STAFF OF THE JOHNS HOPKINS HOSPITAL

PREFACE.

It is nearly a generation since Alfred Poussin wrote in his "Tumeurs de la Vessie" (1884) that the three principal modes for investigation of the lower urinary tract were:

(a) by hypogastric palpation and rectal touch;

(b) by vesical catheterization;

(c) by digital exploration of the bladder.

And now, after only three decades, all is changed, and the cystoscope has literally illuminated the entire field of urinary pathology, creating a vigorous specialty out of an incoördinate mass of imperfect clinical observations and occasional operative procedures.

My own labors in this field began in the Kensington Hospital, Philadelphia. I was helped by the personal kindness of Professor Rudolph Virchow, who gave me the run of the dead house in the Charité at Berlin, where I did experimental work in catheterizing by Pawlik's method, afterwards visiting Pawlik's clinic with some colleagues in 1889 and witnessing his skillful efforts to slip a delicate metal catheter up to the ureter in the water-distended bladder. In 1893 the whole subject advanced at once from obscurity into the clarity of daylight when it suddenly crossed my mind to look into the air-distended bladder through an open cystoscope, with the patient in the knee-breast position, illuminating the field with a light reflected by an ordinary head-mirror. I could thus easily see and touch and treat all parts of the bladder and pass delicate catheters into both ureters. It was the egg of Columbus and the problem was solved in a moment. One had but to look through the Grunenfeld tube, out of which the oblique window had fallen, to see a whole new realm of pathology open to view, brought suddenly from darkness into the light of day. Since then urology has taken enormous strides and though few seem to be as yet masters of the subject, it may fairly be claimed that the field is nearly worked over and is approaching the status of a completed specialty.

The present work has been undertaken and carried out, in conjunction with my constant associate, Curtis F. Burnam, because no other work has been written which does more than squint at urology from the standpoint of the

female sex. We have frankly taken this aspect of the subject as our fundamental position and have done our squinting in the direction of urological problems in the male.

Mr. Max Broedel, so many years my valued friend and co-worker, has put some eight years of his best work into the numerous illustrations which do so much to elucidate the text.

HOWARD A. KELLY.

BALTIMORE.

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CHAPTER I.

TOPOGRAPHICAL ANATOMY OF THE LUMBAR REGION.

INTRODUCTORY.

Owing to the position of the kidneys in the posterior part of the abdominal cavity, in an operation the organ is almost exclusively approached from behind; i. e., through the lumbar region. This route is to be preferred for the reason that through a lumbar incision a kidney can be exposed without injury to the peritoneum, the mesocolon, and the organs of the upper abdominal cavity, which are all situated in front of the kidneys. Through the arrangement of the peritoneum and renal fascia, the kidneys are shut off from the general peritoneal cavity, and are embedded in two separate pockets on either side of the vertebral column, the natural approach to which is through the lumbar region, just below the last rib.

We shall therefore begin with a description of the topography of the lumbar region, noting the outside appearance of the body, and following this with a brief review of the muscles and fascia concerned; finally we shall dwell upon the vessels and nerves supplying this portion of the body. Due consideration will also be given to the significance of the vertebral column and ribs, and of the diaphragm and pleura.

Before studying the muscles and fascia of this region, it is well to examine the exterior skin surface and note its main characteristics as they present themselves on inspection and palpation.

The measurements of corresponding distances in different individuals, of course, vary greatly. The distance from the thoracic cage to the crest of the ilium (Fig. 1, X) often appears short in individuals having a long XII rib,

especially if this rib runs at an angle of 45 degrees or less to the middle line; and in persons whose IV lumbar vertebra is on a level with the iliac crest. On the contrary, this distance is abnormally long in bodies where the XII rib is wanting or insufficiently developed, or if there are six lumbar vertebræ.

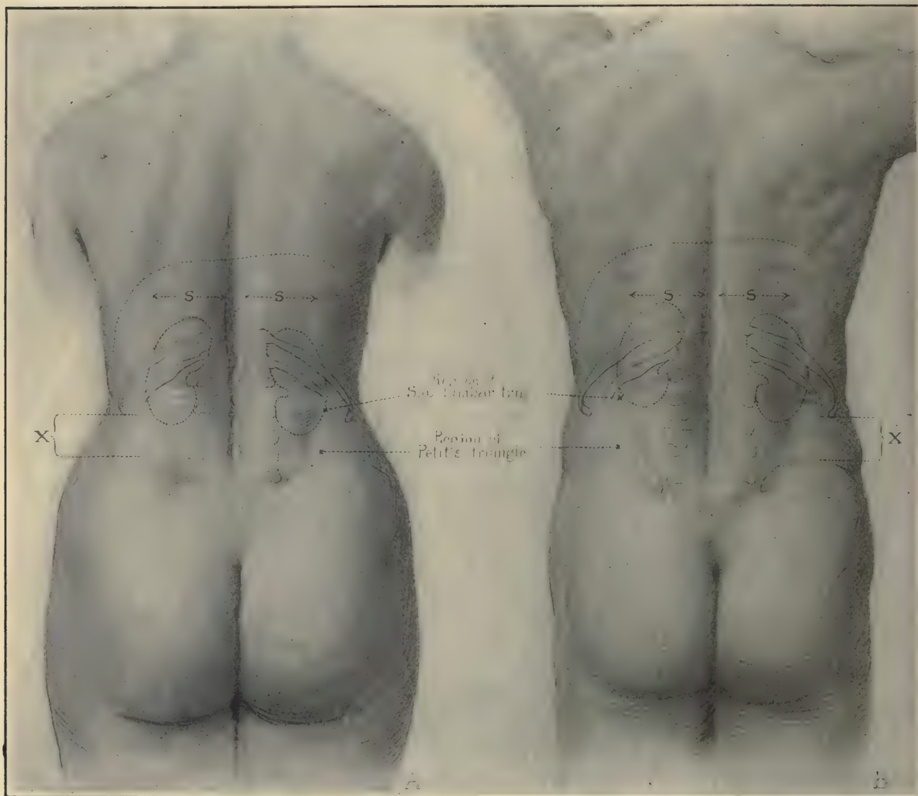


FIG. 1.—POSTERIOR VIEW OF LUMBAR REGION. A, female; B, male; showing position of kidneys in relation to spinal column, M. sacro-spinalis (S), pelvis and ribs.

This distance (X) can be increased on the right side by bending the body forward and to the left, and *vice versa.* As seen later, this is important in the position of patient for operation.

On either side of the central furrow, which corresponds to the spinous processes of the vertebræ, are two thick, muscular bodies, the Mm. sacro-spinalis (SS). On the lateral margin of these muscles, inside and above the area (X), are shallow depressions marking a region in the posterior abdominal wall,

which is almost devoid of muscular covering. The lower portion of this space is termed Petit's triangle or (trigonum lumbale), and the region just above this triangle, i. e., laterally to the belly of the M. sacro-spinalis and just below the tip of the XII rib (see Fig. 1), the superior lumbar trigonum. These two areas are the weakest spaces of the posterior abdominal wall, and abscesses in this locality frequently point through them. They are well adapted for lumbar punctures, especially the upper area, on account of its closer proximity to the kidney.

These landmarks stand out prominently in muscular persons as well as in emaciated bodies. In cases where there is much subcutaneous fat they are not so easily distinguishable, but can, however, be readily outlined by means of palpation.

A considerable difference exists in the topography of the lumbar region in the two sexes (see Fig. 1, A and B). Roughly speaking, the lumbar region in the female may be compared to a section of a cone, whose imaginary apex is in the thorax, while the same region in the male is of a more cylindrical shape. The factors producing these differences in the female are narrowness (partly acquired) of the lower thorax and greater width of the pelvis. In the male, however, the lower ribs are more horizontal, giving the chest a greater width, while the transverse measurement at the level of the iliac crest is relatively small.

THE MUSCLES AND FASCIÆ OF THE LUMBAR REGION.

These will be pictured and described on the right side of the body, as this side is more frequently approached in renal operations, and the description will take up the different layers beginning at the surface. The body is represented bent in a position which lengthens the distance between the XII rib and the iliac crest.

First Layer.—Having dissected off the skin, the subcutaneous fat and fascia superficialis, as shown in Figure 2, we find the lumbar region covered by three large muscular surfaces, medianward by the M. sacro-spinalis, above by M. latissimus dorsi, and laterally by the M. obliquus externus. The fibers of the first-named muscle run almost parallel with the long axis of the body; those of the latissimus are directed obliquely downward and backward, so that they form about a right angle with the lower ribs; the fibers of the obliquus externus finally run downward and to a slight degree forward, at about an angle of 20 degrees to 30 degrees to those of the latissimus. The sacro-

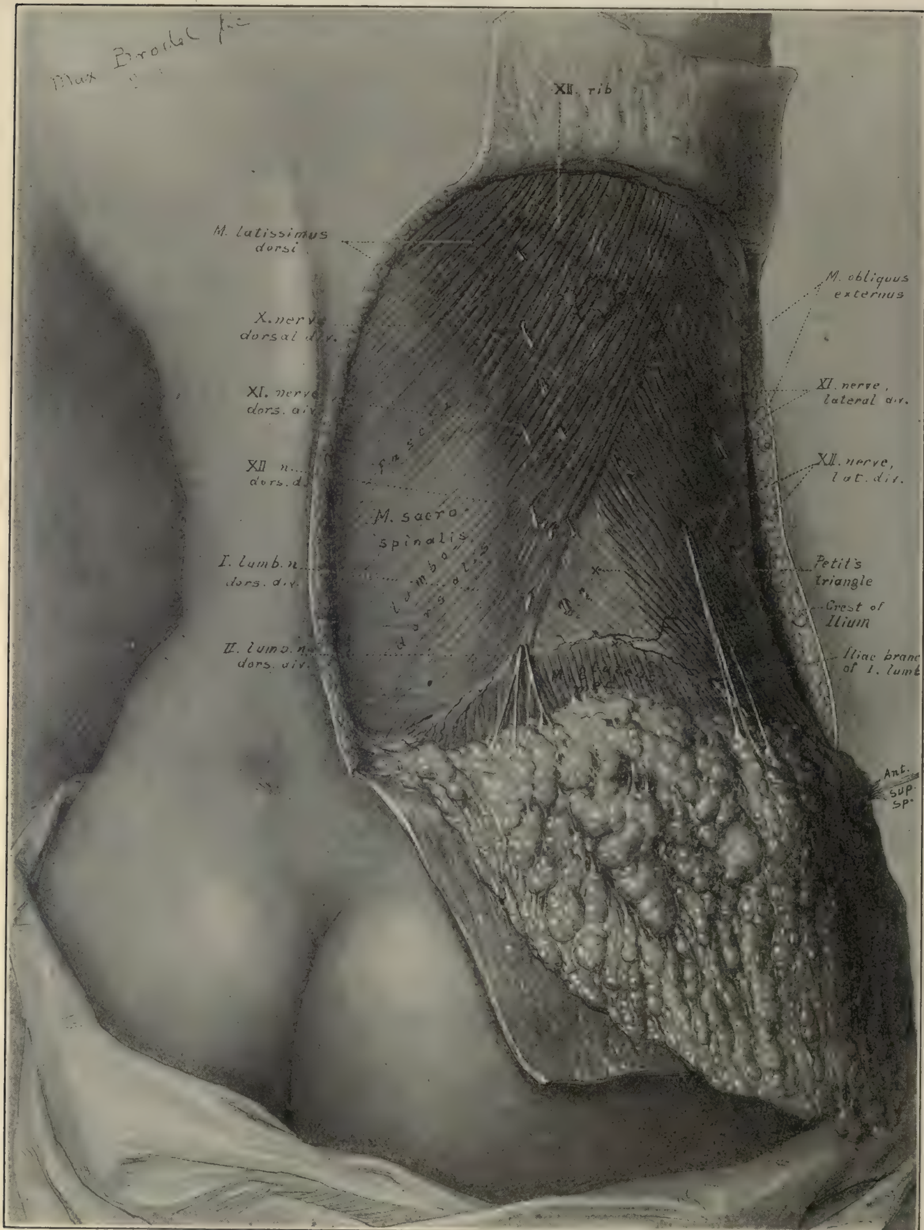


FIG. 2.—POSTERIOR VIEW OF LUMBAR REGION, SHOWING SUPERFICIAL LAYER OF MUSCLES.

spinalis is by far the strongest of the three, the other two being broad and relatively thin muscles.

Petit's Triangle.—A glance at Figure 2 shows between the anterior

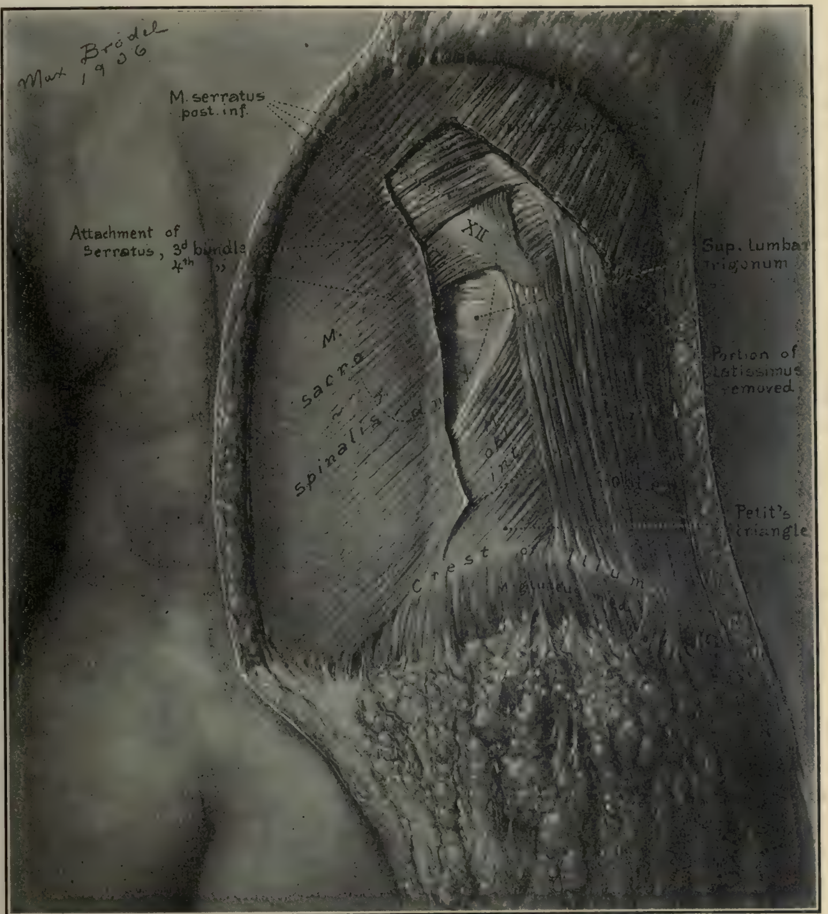


Fig. 3.—Portion of M. Latissimus Dorsi Removed, Showing Relation of Superior Lumbar Trigonum.

bundles of the latissimus dorsi and the posterior fibers of the external oblique a triangular area called Petit's triangle. The base of this is formed by the crest of the ilium. It appears as a slight depression in the muscular wall of the lumbar region, and is filled by a deposit of subcutaneous fat, here more abundant than elsewhere in the neighborhood. In some individuals the fibers

of the latissimus dorsi are attached farther forward on the iliac crest, or may even overlap the posterior border of the external oblique. In consequence, Petit's triangle is very small or may altogether disappear; but if the anterior fibers of the latissimus dorsi are relatively short Petit's triangle will reach considerably higher. The abdominal wall in this region is comparatively thin, consisting from without inward of skin, subcutaneous tissue, fascia superficialis, fat, a few fibers of the internal oblique above with its thin tendinous attachment below and the aponeurosis of the M. transversalis near its junction with the thick lumbar fascia. In the deeper parts of this region are the inferior and lateral fibers of the M. quadratus lumborum, forming the only strong muscular support of the median portion of Petit's triangle, the lateral portion being practically devoid of muscular fibers. The fascia forming the floor of this triangle is perforated by the posterior and lateral branches of the inferior thoracic and superior lumbar vessels and nerves. Through the opening thus formed there is a direct communication between the retroperitoneal and subcutaneous fat. Hence it is that perirenal abscesses, having broken through into the retroperitoneal fat, readily penetrate the fascia and appear beneath the skin covering Petit's triangle. Punctures of such abscesses are best effected in this locality. The lower pole of the normally situated kidney is found at the upper median portion of this triangle, therefore direct a puncture upward and inward, thus avoiding the peritoneal reflection not infrequently found along a vertical line corresponding to the anterior limit of Petit's triangle.

Superior Lumbar Trigonum (Fig. 3).—Above Petit's triangle there is another weak space in the abdominal wall, the superior lumbar trigonum. This is a region, bordered,—

Laterally by the posterior margin of the M. obliquus externus and tip of XII rib,
Above by the lateral margin of the M. serratus posticus inferior,
Below by the edge of the M. obliquus internus,
Mesially by the lateral margin of the M. sacro-spinalis.

The superior lumbar trigonum is covered by the latissimus dorsi, which is, however, only a very thin muscular sheet. Should the latissimus not extend as far down as shown in Figure 3, the anterior portion of the superior lumbar trigonum would have no muscular covering whatsoever. If we dissect away the thin fibers of the latissimus, the superior lumbar trigonum is covered only by the fascia lumbo-dorsalis at its junction with the aponeurosis of the M. trans-

versalis, which in this region is of considerable strength. The fibers of this aponeurosis are directed transversally as shown in Figure 3.

Beneath this fascia, toward the median portion of the superior lumbar trigonum, are the lateral fibers of the quadratus lumborum (Fig. 6), the lateral portion of the trigonum being devoid of muscular fibers. The outline of the lower pole of the kidney is drawn in order to show the favorable position of the trigonum for surgical purposes. (Fig. 3.)

Fascia Lumbo-dorsalis (Lumbar fascia).—Before describing the muscles of the lumbar region in detail it will be necessary to give a description of the fascia lumbo-dorsalis, or lumbar fascia. As nearly all the muscles in this region are connected with this fascia, it is the most important aponeurosis of the lumbar region.

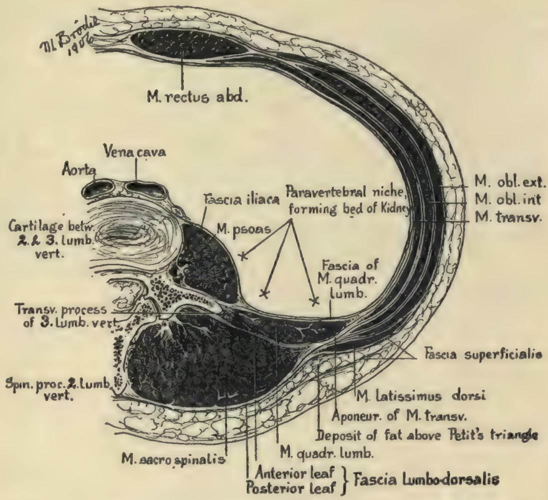


FIG. 4.—TRANSVERSE SECTION OF BODY, SHOWING FASCIA LUMBO-DORSALIS.

The lumbar fascia consists of two leaves, a superficial (posterior) and a deep (anterior), which envelop the M. sacro-spinalis, forming a strong sheath for this muscle. At the lateral margin of the sacro-spinalis the two layers join and form the aponeurosis of the M. transversalis (Figs. 4 and 6). The posterior (superficial) leaf, which is the stronger, is attached to the spinous processes and supraspinous ligaments of the lumbar vertebræ and in part to the ilium and sacrum. The fascia of the latissimus dorsi and M. serratus posticus arise from this superficial layer (Figs. 2, 4, and 6). The anterior (deep) leaf is attached to the posterior surface of the transverse processes of the lumbar vertebræ. In its upper portion it is strengthened by the ligamentum lumbo-costale (Figs. 5, A and B). As shown in Figures 5, A and B, the ligamentum lumbo-costale is relatively in the same position in cases either with long, short, or deficient XII rib. In front of this anterior leaf is the covering of the M. quadratus lumborum, described by some writers as a third division of the lumbar fascia (Figs. 4 and 6). It is thin, and arises from

the anterior surface of the transverse processes, and passes in front of the M. quadratus lumborum. The upper portion is strengthened by the ligamentum arcuatum Halleri (Figs. 6 and 7), which is about in the same position as the ligamentum lumbo-costale, but anterior to it, where it serves as an origin for the posterior muscular bundles of the diaphragm. Both these ligaments form a very strong band from the I and II lumbar vertebra to the lowest rib, and, although effectually protecting the pleura during a renal operation, may

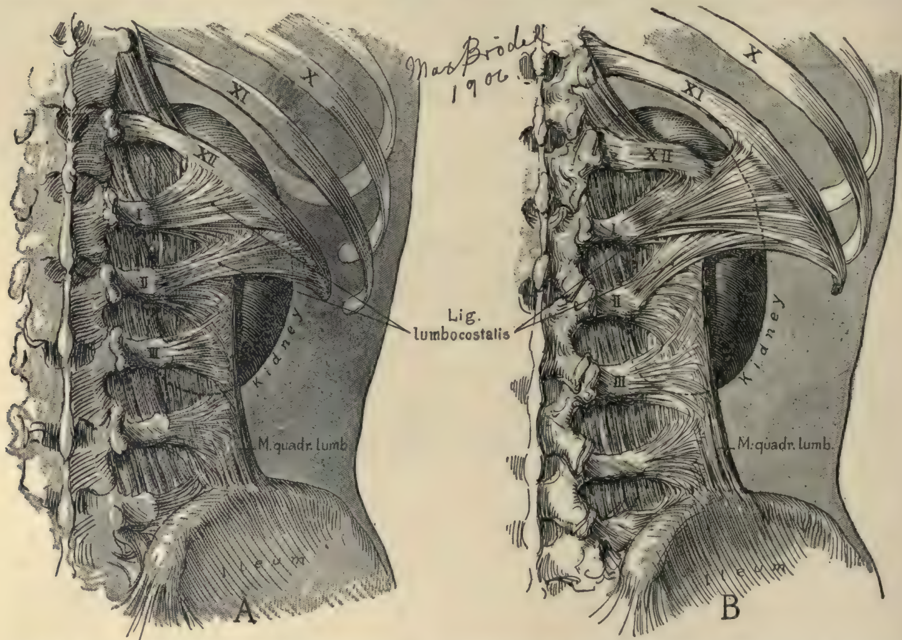


Fig. 5.—Ligamentum Lumbo-costale. A, position in cases with well-developed twelfth rib; B, with rudimentary or missing twelfth rib.

sometimes form quite an obstacle to the easy exposure of the kidney, especially if the organ lies high and is fixed.

In kidney incisions the lumbar fascia comes into consideration only as far as its lateral portion is concerned, i. e., laterally to the outer fibers of the M. quadratus lumborum, where it fuses into the aponeurosis of the broad abdominal muscles. In this region its fibers run transversely, similar to the muscle bundles of the M. transversus abdominis. Being much thinner, the other fasciæ of the lumbar region are relatively unimportant.

They are:

Fascia superficialis (Fig. 4),

a thin fascia, situated just below the skin and covering the entire outer muscular coat of the back,

Fascia iliaca (Figs. 4 and 6),

a thin fascia, situated anterior to the fascia of the M. quadratus lumborum and covering the entire inner muscular surface of the lumbar region. Between this layer and the fascia of the quadratus lumborum there is a layer of fat, retroperitoneal fat. The fascia iliaca is sometimes spoken of as the posterior leaf of the fascia renalis propria, or the retroperitoneal fascia.

To recapitulate, in approaching the kidney, through the superior lumbar trigonum, we encounter the following fascia:

I. The moderately thick fascia superficialis (just beneath the skin),
II. The thick lumbar fascia, here forming the aponeurosis of the M. transversalis,
III. The insignificant fascia of the quadratus lumborum (third leaf of fascia lumbo-dorsalis),
IV. The relatively strong fascia iliaca (fascia retro-renalis).

SURGICAL RELATIONS OF MUSCLES OF THE LUMBAR REGION.

The surgical relations of the muscles encountered in renal incisions will now be considered.

The Superficial Layer.—The latissimus dorsi is a broad, thin, triangular muscle having its apex below, posterior to Petit's triangle. Above its tendinous attachment is from the spinous processes and ligaments of the four or five lower thoracic vertebræ, while below its muscular fibers arise from the superficial layer of the lumbar fascia (Figs. 2 and 6). Its lowest bundles are attached by a tendon to the upper edge of the ilium. While in the lumbar region its bundles pass at right angles to the lowest ribs; higher up they run more transversally. The lowest ribs are covered by the muscle. From the tips of the last three or four ribs a few separate bundles arise, which form the most lateral portion of the latissimus dorsi. The lower portion of the muscle is stronger than the upper. In renal incisions the muscle need not be cut, as its lower fibers can easily be separated without injury to the nerves or the vessels found at a greater depth. The nerve supply of the latissimus dorsi is derived from the dorsal branches of the thoracic nerves.

M. Sacro-spinalis (Figs. 4 and 6).—This is a thick, long muscle, which is situated on either side of the middle line, encased in a strong sheath

(Fig. 6) formed by the two leaves of the lumbar fascia. On transverse section the muscle presents a triangular appearance, the thinnest part being at the sides. Its deep origin is muscular, while below it has a tendinous attachment to the iliac crest, the posterior surface of the sacrum, the spinous processes of the lumbar vertebræ, and also to the inner surface of the lumbar fascia. A

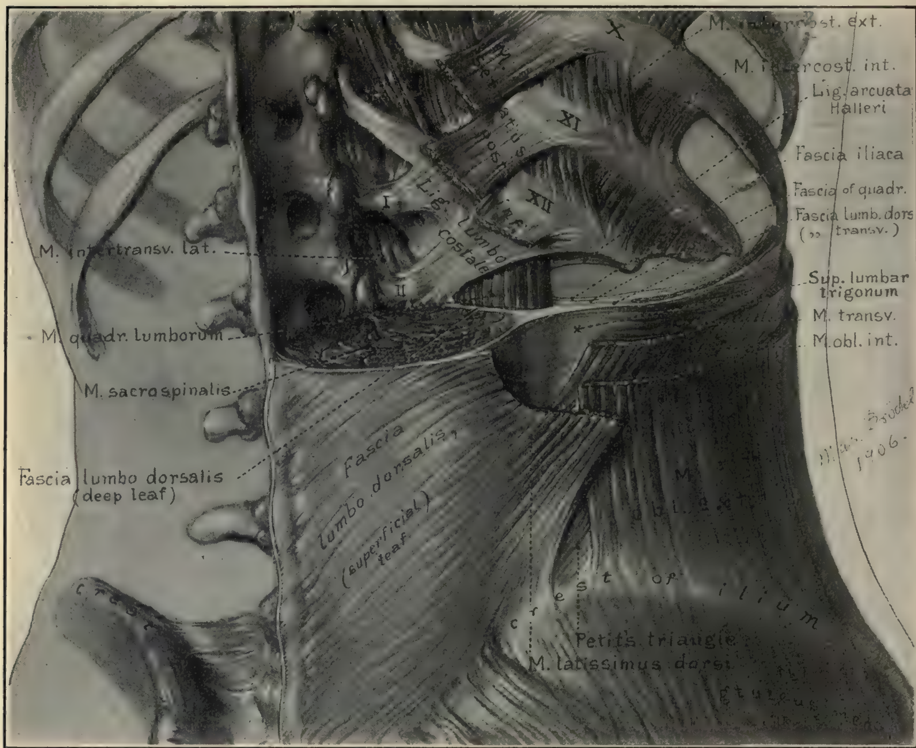


FIG. 6.—DISSECTION, SHOWING RELATION OF ALL THE MUSCLES OF THE LUMBAR REGION.

short distance below the XII rib the sacro-spinalis divides into three separate muscles, which run upward nearly parallel to one another: M. ilio-costalis, M. longissimus, M. spinalis.

In kidney incisions only the lateral bundles of the sacro-spinalis (M. ilio-costalis lumborum) require consideration, and this only when the usual incisions lateral to the sacro-spinalis do not afford sufficient room. If cut, the incision should be made transversely to its fibers, 3-4 cm. below and parallel to the XII rib, in order to avoid the larger vessels and the lateral and ventral

branches of the last thoracic and first lumbar, as well as the dorsal branches of the X and XI thoracic nerves.

M. Obliquus Externus (Figs. 3, 4 and 6).—This is the last muscle of the first layer. It consists as a rule of seven flat muscle bodies, which arise from the seven lower ribs. Occasionally there are additional bundles, one coming from the V rib above and another from the lumbar fascia in the prolongation of the transverse process of the first lumbar vertebra. (Fig. 2.) A similar condition is found if the XII rib is very short or wanting, in which case the posterior margin of the M. obliquus externus extends further back than shown in Figures 3 and 6, making Petit's triangle and the superior lumbar trigonum narrower.

The muscle bundles originate from the ribs in short tendons, each bundle overlapping the edge of the next one below, those inserted to the X, XI, and XII ribs being covered by the M. latissimus dorsi. The posterior bundles of the external oblique run almost perpendicularly down from the tip of the XII rib to the crest of the ilium (Figs. 3 and 6), where their fasciæ become continuous with that of the gluteus medius. In renal incisions only the posterior portion of the muscle need be considered, that is, the part shown in Figure 3. The most posterior fibers generally run from the XII rib to the iliac crest, at a point 8 to 10 cm. from the median line. In approaching a kidney these are readily drawn forward, except where the external oblique reaches very far back, when its fibers can be separated and pulled apart, giving an opening of moderate size, though relatively small, because of the shortness of the posterior fibers of the muscle. If a larger incision is required and the muscle has to be cut, let the incision pass obliquely to its fibers, parallel to the lower ribs, to avoid cutting the nerves, which pass in this direction. The nerve supply of the external oblique comes from the ventral branches of the VIII to the XII thoracic and from the ilio-hypogastric and inguinal (I lumbar).

The Second Layer.—M. Obliquus Internus (Figs. 3 and 6).—The internal oblique, which belongs to the second layer of muscles, lies immediately below the external oblique (Fig. 6). Its posterior bundles run almost parallel to those of the latissimus dorsi, i. e., at right angles to the lower ribs, and therefore its posterior portion extends farther back than that of the external oblique (Fig. 6). The internal oblique originates (beginning posteriorly) from the anterior leaf of the lumbar fascia about 5-7 cm. from the median line, from the intermediary line of the iliac crest, and anteriorly from Poupart's ligament. The posterior portion runs obliquely upward and becomes attached to the lower margins of the XII, XI, and X ribs. The rest of the fibers coming from the crest of the ilium and from Poupart's ligament pass anteriorly, spread-

ing out like a fan over the abdomen. We are concerned more especially with the posterior portion of the internal oblique. Like the external oblique, th posterior margin of the internal oblique can also be pulled laterally in approac ing the kidney. Should it be necessary to cut the muscle, this must be do in a direction at right angles to its fibers, again parallel to the lower ribs, order to avoid dividing the before-mentioned nerves.

The nerve supply of the internal oblique is the same as that of the extern oblique.

M. Serratus Posticus Inferior.—This belongs also to the seconc layer of the lumbar muscles. Its lowest border is found in a line connecting the II lumbar vertebra with the outer third of the XII rib (Fig. 3). It is very thin and consists of four leaves which arise from the lumbar fascia in the vicinity of the XI and XII thoracic and I and II lumbar vertebræ. These lamellæ pass obliquely upward and outward to be inserted to the four lower ribs. The upper and lower leaves are often poorly developed, or may, indeed, be lacking. The lowest leaf, which may in cases of a high and fixed kidney form an obstacle to a sufficient exposure of the organ, need only be noted here. This lamella is situated almost in the same position as the ligamentum lumbocostale (Fig. 6), which lies, however, beneath it, acting as a support of the upper portion of the deep leaf of the lumbar fascia. As the pleura is about on the same level with this ligament, or only a short distance above it, an incision ought not to injure either the muscle or ligament. If it be necessary to resect a portion of the XII rib, only the outer third should be removed, the periosteum being carefully preserved, in order to secure an additional protection for the pleura. The nerve supply of the M. serratus is derived from the anterior branches of the IX, X, and XI thoracic nerves.

The Third Layer.—M. Transversus Abdominis.—This belongs to the third layer of muscles of the lumbar region, and is the deepest of the three broad abdominal muscles. Its fibers run transversely around the lateral abdominal wall (Fig. 6). Its uppermost bundles arise from the inner surface of the costal cartilages of the seven lower ribs; the middle ones, which concern us more, arise from the junction of the two leaves of the lumbar fascia (Figs. 4 and 6), while the lowest come from the inner portion of the iliac crest and Poupart's ligament. Anteriorly, along the outer border of the M. rectus abdominis (linea semi-lunaris Spigeli), the fibers run into an aponeurosis, the upper two-thirds of which forms the posterior leaf of the sheath of the rectus.

In the renal region, i. e., the vicinity of the superior lumbar trigonum, the muscular fibers of the transversalis are few and thin, and may even be lacking, in which case the muscle begins some distance anterior to the trigonum.

Whether it contain muscle fibers or not, the aponeurosis in this region must be divided to gain access to the kidney. This is best done by bluntly perforating the fascia transversalis at about the center of the trigonum, and pulling apart the fibers of the fascia and muscle; a very simple procedure and one which yields an opening of sufficient size for the majority of renal operations. The direction of the fibers is transverse and almost parallel to the ribs, approximately the same as that of the vessels and nerves found in this region just beneath the fibers of the transversalis. As before mentioned, the upper portion of the transversalis fascia close to the XII rib is considerably strengthened by the ligamentum lumbo-costale (Figs. 5 and 6). The nerves to the transversalis are derived from the anterior branches of the VIII to the XII thoracic and I lumbar.

M. Quadratus Lumborum (Figs. 4, 5, 6 and 7).—This is a flat, rectangular muscle, situated in front of, and in immediate contact with, the anterior (deep) leaf of the lumbar fascia. Its upper and median portion is covered anteriorly by the M. psoas major. Its origin below is a short tendon from the inner portion of the iliac crest, ilio-lumbar ligament, and transverse processes of the lower lumbar vertebræ; also from the lumbar fascia. Above, it is attached by two to three bundles to the transverse processes of the two upper lumbar vertebræ, and to the lower edge of the XII rib. This last-mentioned portion is the strongest part of the muscle. If the XII rib be wanting, the quadratus lumborum is attached to the XI rib. The lateral border of the muscle is free, and is felt as a strong ridge between the XII rib and crest of the ilium at a distance of about 8 to 9 cm. from the middle line. The quadratus lumborum is encased in a sheath of fascia, the posterior portion of which is the strong deep leaf of the lumbar fascia, separating the quadratus lumborum from the sacro-spinalis (Fig. 6). The upper region of this fascia is strengthened by the ligamentum lumbo-costale, a strong band, which, as we have seen, is found constantly and in the same position, regardless of the topography of the XII rib (Figs. 5, A and B). This fascia and ligament are attached medianwards to the posterior surface of the transverse processes of the lumbar vertebræ and the posterior surface of the XII rib.

The fascia forming the anterior portion of the sheath of the quadratus lumborum is relatively thin. Although described by some writers as a third lamella of the lumbar fascia, its embryology proves that it is the fascia of the quadratus lumborum. Its upper portion is strengthened by the ligamentum arcuatum (Halleri) (Figs. 6 and 7), the fibers of which are interlaced with those of the fascia. The fibers of the ligamentum arcuatum, which consists of two portions, a median and a lateral arch, form the origin of the lateral

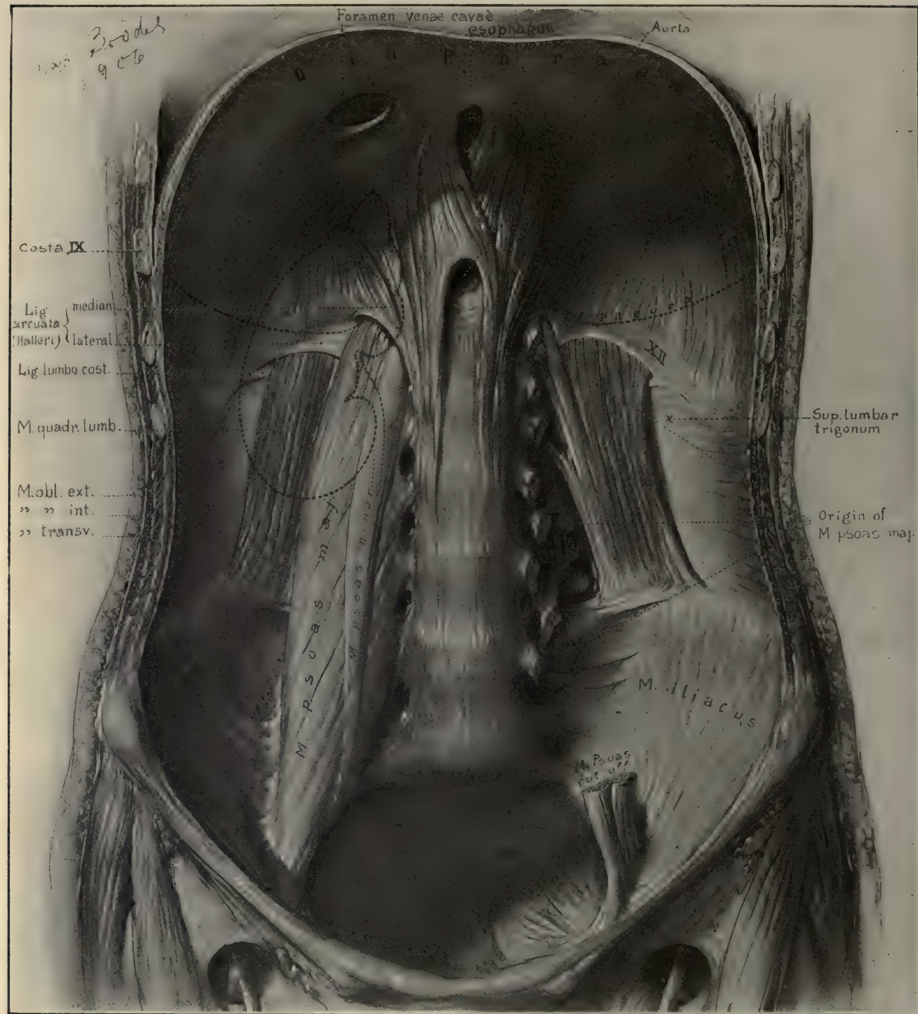


FIG. 7.—THE LUMBAR REGION VIEWED FROM THE FRONT. Viscera and Peritoneum Removed.

bundles of the vertebral portion of the diaphragm (Fig. 7). The fascia and ligament just described are attached medianward to the anterior surface of the transverse processes of the lumbar vertebræ, near their base, and to the anterior surface of the XII rib. They separate the M. quadratus lumborum from the M. psoas major.

Between the lateral border of the quadratus and the tip of the XII rib the two ligaments (lumbo-costale and ligamentum arcuatum) join and form a strong band, protecting the pleural cavity, situated a short distance above.

A kidney in normal position extends from 1 to 3 cm. laterally to the lateral margin of the quadratus lumborum; therefore, it is not necessary to sacrifice the muscle to obtain a good exposure, as the quadratus lumborum can readily be drawn medianward, just as much room being thus gained as though the muscle were cut. In doing this let it be remembered that across the inner surface of the muscle in an oblique direction (parallel to the lower ribs) there are the ventral branches of the last thoracic and first lumbar nerves. The XII thoracic runs parallel to the XII rib, curving somewhat downward, and perforating the M. transversalis at a varying distance below and lateral to the tip of the XII rib. The I lumbar consists, as a rule, of two trunks, an upper larger (ilio-hypogastric) and a lower smaller (inguinal). These run from a point near the transverse process of the II lumbar vertebra obliquely down to the lateral part of the iliac crest. When they reach the outer margin of the quadratus lumborum they are as a rule 1 to 2 cm. above the iliac crest. This distance, however, varies considerably, and the nerves may run much higher or reach the crest at the same point where the quadratus arises. (See description of the nerves, page 21.) In drawing the quadratus aside the I lumbar nerve is always seen and can accordingly be avoided. Both the XII thoracic and I lumbar nerves contain sensory and motor fibers, their motor branches being distributed over wide muscular areas on the abdomen. Let injuries to these nerves be carefully avoided, and if cut by accident, or if the operation has necessitated doing so, an anastomosis of the two ends should always be done before closing the incision. The nerve supply of the M. quadratus lumborum is derived from the muscular branches of the lumbar plexus.

M. Psoas Major (Fig. 7).—In renal operations the psoas, owing to the depth at which it is situated, never comes directly into consideration; it serves, however, partially as a support of the kidney, whose posterior surface and hilum lie against the upper portion of the muscle as upon a cushion.

The psoas is a long muscle which arises from the bodies and transverse processes of the XII thoracic and all the lumbar vertebræ. Its bundles converge downward, forward, and outward, terminating in a tendon attached to the lesser trochanter of the femur. It occupies the space between the vertebral column and the anterior median surface of the quadratus lumborum and iliacus. Its nerves are derived from the lumbar plexus.

THE BLOOD VESSELS.

The Arteries.—The blood vessels supplying the lumbar region are the last intercostal, the subcostal (or XIIth), and the upper lumbar arteries and veins (see Fig. 8). The main trunks of these vessels are situated at a much higher level than their terminal branches. These are arranged in such a manner that the areas supplied by them overlap as do the shingles on a roof. It follows that in an incision made in the lumbar region, just below the last rib, the vessels encountered in the superficial layers, skin, subcutaneous fat, etc., are those derived from a comparatively high source, i. e., from the last two intercostal arteries; those in the middle layer being derived from the subcostal artery; and those in the lowest layer from deep branches of the subcostal and first lumbar arteries. A glance at Figure 8 shows the superior lumbar trigonum to be a practically nonvascular area; the subcostal artery well above it, the lateral cutaneous branch of which artery runs in front of it, piercing obliquely through the broad abdominal muscles and entering the subcutaneous fat midway between the last rib and the crest of the ilium, or below that point, and from 3 to 5 cm. anterior to the trigonum. The lower portion of the trigonum comes in the vicinity of the anterior division of the first lumbar artery, which, however, is often very small. Figures 8, 10, 11, and 12 show that the subcostal (XII) artery is the one which plays the most important rôle in a lumbar incision. Its area of distribution is generally somewhat larger than that of the other costal and much more extensive than that of the lumbar arteries. The terminal branches are seen anastomosing or encroaching upon the territory of the lumbar arteries medianward, the ilio-lumbar and circumflexa ilium profunda below, the inferior epigastric anteriorly, and the intercostals above.

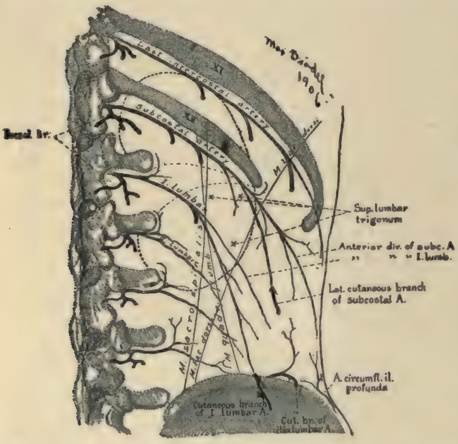


FIG. 8.—SCHEMATIC REPRESENTATION OF THE ARTERIAL BLOOD SUPPLY OF THE LUMBAR REGION. Note the relative shortness of the lumbar arteries.

The subcostal artery, like the lumbar arteries, arises from the posterior part of the aorta (Fig. 9). Occasionally there is one common trunk from

which the right and left arteries are derived, or, again, two vessels on the same side may arise from one trunk at the aorta.

The main trunk of the vessel is seen curving and hugging closely the body of the vertebra. The left is shorter than the right, owing to the position of the aorta. In its course the artery passes beneath the crura of the diaphragm and the psoas muscle, to which little twigs are given off. In the space between

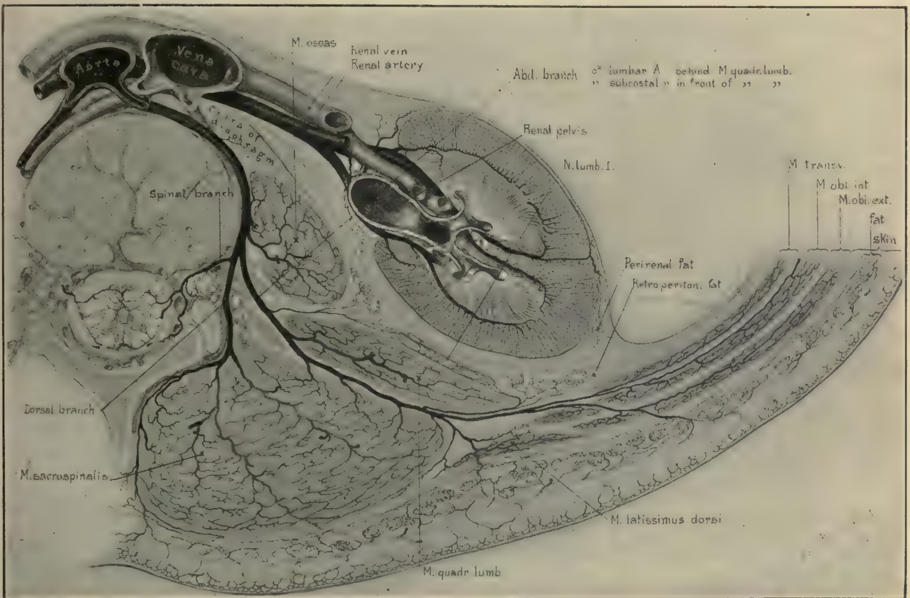


FIG. 9.—SCHEMA REPRESENTING COURSE AND DISTRIBUTION OF THE SUBCOSTAL AND LUMBAR ARTERIES. The vessels have been drawn as though in one level, in reality they run obliquely downwards, piercing the superficial muscles at a lower level than the deep ones.

the transverse processes the artery divides into two branches, a ventral and a dorsal. While the ventral or abdominal branch of the subcostal artery is of considerable size, it is comparatively small in the lumbar arteries, and has also a different course in relation to the M. quadratus lumborum. The abdominal branch of the subcostal artery passes in front of the muscle, while that of the lumbar arteries runs behind, i. e., between it and the M. sacro-spinalis, as shown in Figure 9. Occasionally, however, the abdominal branches of the two upper lumbar arteries pass in front of the quadratus lumborum.

Before the vessel reaches the lateral border of the M. quadratus lumborum it gives off branches to this muscle and also a few to the M. sacro-spinalis.

There are also small branches emerging between the quadratus lumborum and psoas, curving around the lateral border of the former, running to the fat, and supplying the sheaths of the nerves. At the lateral border of the sacrospinalis is a branch supplying the latissimus and lumbar fascia, emerging through this muscle to terminate in the skin. The lateral border of the latissi-

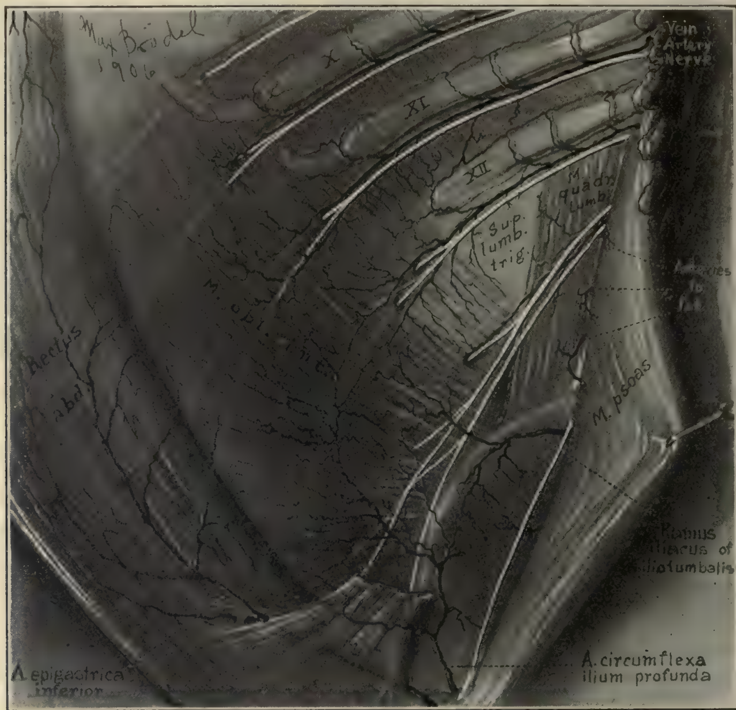


FIG. 10.—THE LUMBAR AND LOWER THORACIC NERVES AND VESSELS VIEWED FROM THE ABDOMINAL SIDE. M. transversalis dissected off.

mus is free from larger branches, which explains why this muscle can be bluntly dissected off without hemorrhage, and so easily pushed medianward.

The main trunk of the abdominal division passes now outward and downward to the broad muscles of the abdomen. It remains for a distance of a few centimeters below the lumbar fascia, where it gives off a large branch, the lateral cutaneous division, which runs downward, piercing in quick succession the abdominal muscles to supply the skin over the lateral portion of the lumbar region. It is accompanied by the lateral cutaneous branch of the corresponding spinal nerve. An incision in the lumbar region, parallel to the ribs,

directed between the subcostal and the first lumbar arteries, will invariably sever this branch and its accompanying nerve, also the superficial or terminal branches of the lateral cutaneous branch of the last intercostal vessel and nerve, which run in the skin overlapping this area from above.

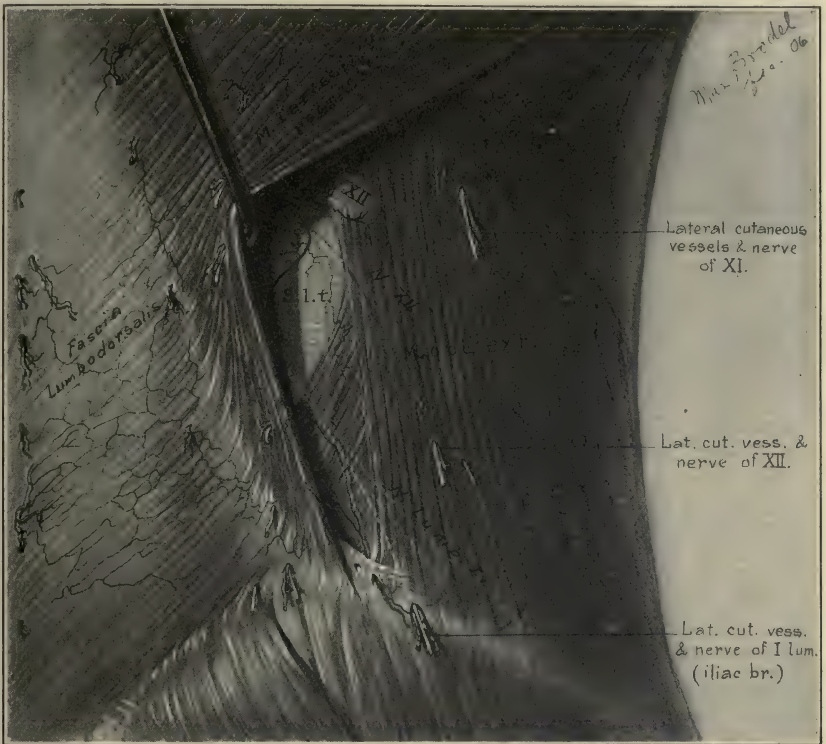


FIG. 11.—SUPERFICIAL VASCULARIZATION OF THE SUPERIOR LUMBAR TRIGONUM AND ITS VICINITY.

The arterial supply of the external and internal oblique and transversalis is such that the majority of large branches remain between the second and third layer, i. e., between the internal oblique and transversalis, to which muscles small branches are given off (Figs. 9, 10, 11, and 12). There are few or no large branches between the external and internal oblique, as most of the arteries of the former run in the body of that muscle parallel to the deeper main branches (Figs. 9 and 12).

The branches to the muscle proper are comparatively long and somewhat

tortuous, running parallel to the muscle fibers, hence the possibility of bluntly severing the muscle bundles without hemorrhage.

The dorsal branch (Fig. 9) gives off a small vessel to the spinal canal; passes through the space between the transverse processes and downward into

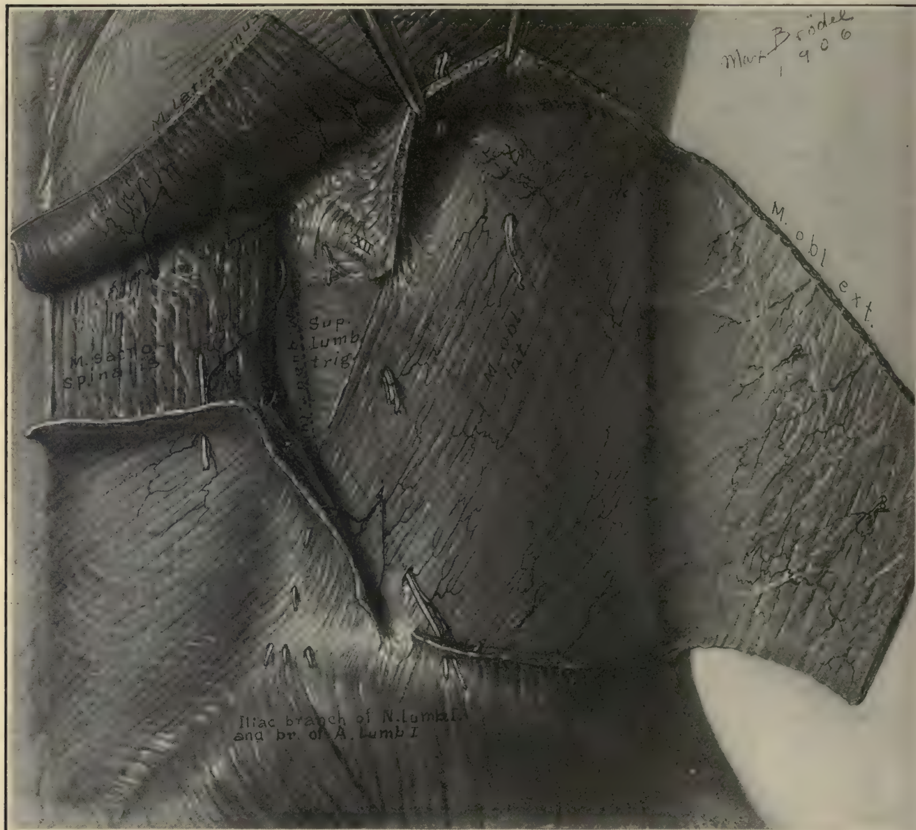


FIG. 12.—DEEP VASCULARIZATION OF THE SUPERIOR LUMBAR TRIGONUM AND ITS VICINITY.

the body of the M. sacro-spinalis, where it divides into two or three main trunks, the largest of which (generally the middle one) pierces the posterior lamella of the lumbar fascia, together with the dorsal division of the spinal nerves, supplying the skin over a large area. A small median branch hugs the spinous processes closely and emerges at the surface near the middle line. The lumbar fascia receives small twigs from these two arteries, also a few from the abdominal division and its branches to the M. latissimus dorsi. On

the surface the main arteries pass between the subcutaneous fat and the skin, where they form a wide-meshed network. From there the branches to the fat run inward; those to the corium are directed to the surface, forming a delicate network with capillary loops in the papillæ (Fig. 9).

The Veins.—The veins in general are seen to accompany the arteries and require no detailed description. They anastomose more freely than the arteries, forming plexuses at the vertebral column (Fig. 9). Around the bodies of the vertebræ they pass between the arteries and the bone and collect on the posterior surface of the vena cava. In front of the transverse processes there is a branch which connects all the lumbar veins, the ascending lumbar vein. It anastomoses as a rule with the V. azygos above and ilio-lumbar and common iliac below. Contrary to the arrangement of the arteries, which are longer on the right, the lumbar veins are longer on the left, a fact to be borne in mind in making traction to expose a kidney. During this procedure the aorta and vena cava are pulled to a varying degree out of their normal position, in the direction of the lumbar incision. Practically the only structures resisting this traction are the lumbar vessels, which anchor the aorta and vena cava in their normal position in front of the spinal column.

Owing to the shortness of the left lumbar arteries and to the strength of the arterial walls, the aorta is more firmly fixed on the left than on the right, so that a kidney is brought into view with greater difficulty on the right side. In addition to this, the renal vein on that side is often a very short vessel, whose delicate walls will stand little traumatism. On the contrary, the renal vein on the opposite side is very long and, owing to the long right lumbar arteries, the aorta follows the traction of the renal artery more readily; therefore, a kidney exposure is, generally, more easily and safely made on the left than on the right side. The difficulties referred to are, of course, much increased if the kidney has a broad pedicle with several separate vessels, or if a pathological process has deprived the vessels of their elasticity (see also chapter on Incisions).

THE NERVES.

The nerves of especial importance in renal operations are the ventral branches of the last thoracic (XII) and the first lumbar. If an incision be carried considerably forward, it may enter the region of the XI nerve; only the terminal filaments of the lateral cutaneous branch of the latter, however, overlapping this region from above, are likely to be encountered.

The superior lumbar trigonum is situated between the XII thoracic and

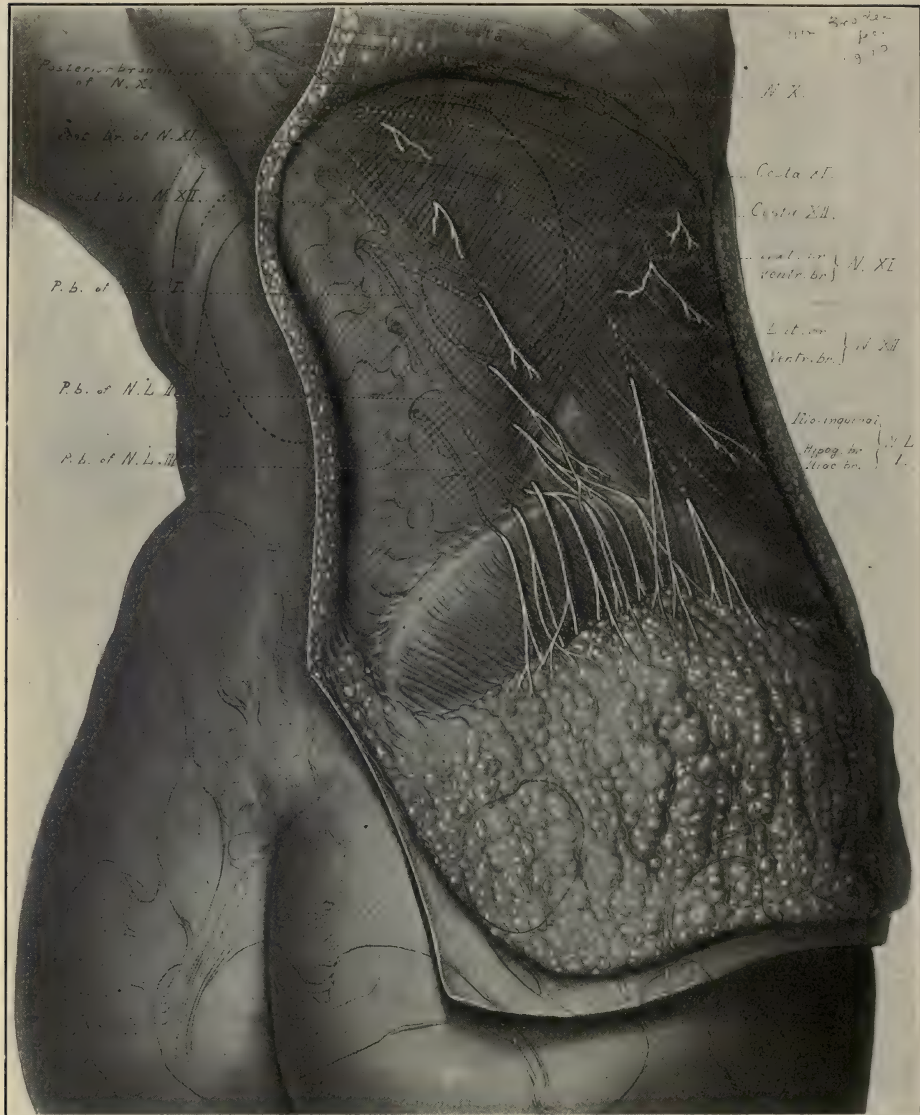


Fig. 13.—The Nerves of the Lumbar Region from Behind.

the first lumbar nerves (see Figs. 10, 11, 12, and 13). The nerves bear the same relation to the trigonum as do the vessels; i. e., the last thoracic runs along the upper border of the trigonum, the lateral cutaneous runs obliquely

forward and downward along the anterior border, while the first lumbar follows a course along its median and lower border.

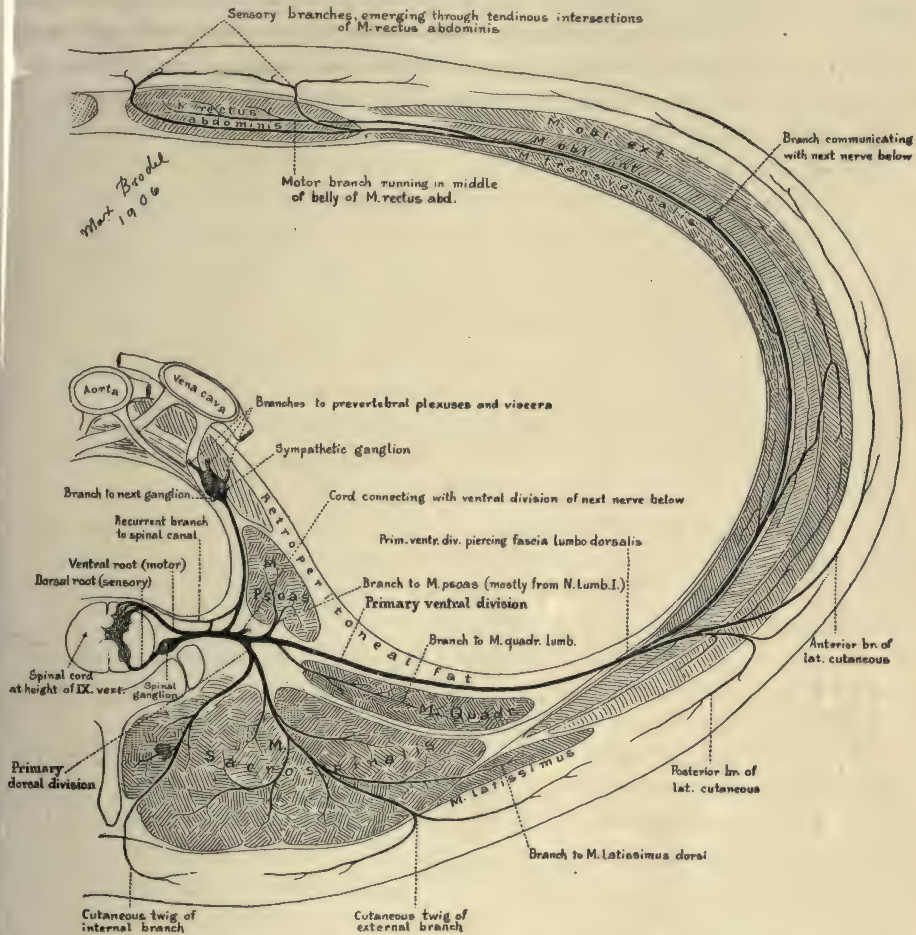


FIG. 14.—SCHEMA REPRESENTING COURSE AND DISTRIBUTION OF THE LAST THORACIC NERVE. The dorsal division, the lateral cutaneous, and the other terminal sensory branches have been drawn as though in the same level. In reality they run obliquely downward.

The nerves are nearly everywhere accompanied by the vessels, whose course we have just considered, the general order in passing out to the abdomen being, —from above downward—vein, artery, nerve.

The terminal branches, especially those of the dorsal divisions, are dis-

tributed over an area much lower than the level of their spinal origin. This general arrangement may be better understood from a description of the last thoracic nerve, whose roots are found between the VIII and IX vertebræ. The ventral division runs downward and forward just below and parallel to the last rib (Fig. 13), its lateral cutaneous branch coming off 2-3 cm. or more laterally to the outer margin of the quadratus lumborum, where it pierces obliquely the broad muscles of the abdomen (Fig. 14). It divides into two branches, an anterior and a posterior, the latter of which courses straight downward over the crest of the ilium to the anterior portion of the gluteal region, occasionally extending as far down as the great trochanter (Fig. 13). The ventral division terminates in the region of the rectus abdominis and the overlying skin area, about midway between the symphysis pubis and the umbilicus. The hypogastric branch arises occasionally, together with the XII, but in the vicinity of the superior lumbar trigonum it is generally found a considerable distance below the ventral branch of the XII. Contrary to the ventral division, which is very long, the dorsal division traverses a much shorter course, and, as its terminal twigs reach almost as low as those of the ventral branch, it follows that its downward direction is more marked than that of the ventral branch (Fig. 13). It plunges into the sacro-spinalis, soon dividing into an external and an internal branch (Fig. 14), the former of which is the larger. This branch, after having given off twigs to the muscle, terminates in the integument over the crest of the ilium and upper portion of the gluteal region (Fig. 13). The internal branch is small and supplies the Mm. multifidus spinæ and longissimus. It rarely becomes cutaneous, but if so the cutaneous branch of the external is correspondingly smaller.

Figure 13 is a composite drawing of the course and distribution of the larger nerves of the lumbar region. The arrangement as pictured occurs most frequently and corresponds to types III-C and IV-A of Bardeen's tables (Fig. 15). The skin over the renal region is supplied by the cutaneous twigs of the X and XI thoracic nerves, seen to emerge close to the costal margin through the fibers of the latissimus and upper portion of the external oblique. The lateral border of the latissimus is devoid of nerves and can be easily lifted up and drawn medianward, thus exposing the superior lumbar trigonum. There are but two nerves in its vicinity (Figs. 10, 11, and 12), the last thoracic and the upper branch of the first lumbar. Both are on the abdominal side of the lumbar fascia and are not visible until the fascia has been incised. Figures 13 and 14 illustrate the relation of the last thoracic nerve to the different layers of muscle and fascia.

Let us now consider the first lumbar nerve and follow it from its

origin to its peripheral distribution. The root origin of the nerve is between the IX and X thoracic vertebræ. The roots descend, pierce the dura mater, and, after passing the ganglia situated near or in the intervertebral foramen, the main trunk emerges from the foramen below the first lumbar vertebra and soon divides into two primary branches, a ventral and a dorsal.

The ventral division concerns us most. It forms the upper portion of the lumbar plexus, which embraces the corresponding divisions of the upper four lumbar nerves, and is located in the substance of the psoas muscle. Above, the first lumbar nerve often communicates with the last thoracic nerve by means of a small branch, the dorso-lumbar cord.

The ventral division, as a rule, separates early into two branches, which run parallel to the corresponding branch of the last thoracic; the upper branch, the ilio-hypogastric nerve, is the larger, while the lower, the inguinal, is the smaller. They are in close contact with each other during their course, or else from 1 to 2 cm. apart. At the outer border of the psoas they are seen emerging between this muscle and the quadratus lumborum, to both of which they give off small branches. They then pass in front of the quadratus lumborum obliquely downward and outward, crossing its lateral border at a variable distance, .05 to 5 cm., from the iliac crest (Fig. 10). The angle which these nerves form with the external margin of the quadratus lumborum is therefore variable, and if the body be bent as in Figure 13, a position used in most renal operations, the quadratus lumborum is considerably stretched and the nerves are apt to appear about parallel to its lateral border.

They extend on the abdominal side of the lumbar fascia to a point about 2-5 cm. lateral to the quadratus lumborum, close to the iliac crest; whence they follow different courses. The higher and larger of the two, the ilio-hypogastric, perforates the transversalis and runs forward for a short distance between this and the internal oblique, to give off a large lateral cutaneous division called the iliac branch (Fig. 13). This is analogous to the lateral cutaneous of the last thoracic nerve, and perforates the external oblique much lower down close to the iliac crest and near its anterior third. Its cutaneous distribution is also correspondingly lower than that of the XII. These two lateral cutaneous nerves are rarely of the same size, their areas being inversely proportional. The main trunk, now hypogastric branch or abdominal branch, remains between the transversalis muscle and the internal oblique, to which it gives off little twigs. Near the anterior-superior spine it often connects with the inguinal nerve, and in certain instances with the ventral branch of the XII. After having perforated the internal oblique it continues its forward course parallel to Poupart's ligament, piercing the aponeurosis of the

external oblique a short distance above the external ring. It terminates in the integument above the symphysis pubis.

The inguinal, the lower and smaller of the two nerves derived from the ventral division of the first lumbar nerve, runs parallel to the ilio-hypogastric, and, while the latter perforates the transversalis near the quadratus lumborum, the inguinal continues along the inner surface of the transversalis until the vicinity of the anterior part of the iliac crest, where it perforates the transversalis. It often communicates, as stated above, with the ilio-hypogastric and, after having pierced the internal oblique, it enters the inguinal canal and runs lateral to the round ligament (or spermatic cord). Its end twigs supply the skin over the pubic region and a part of the external genitalia.

The primary dorsal division of the I lumbar nerve, as well as those of the II and III, has an arrangement similar to that of the dorsal division of the last thoracic nerve. Its external branch is the larger and pierces the sacro-spinalis and the aponeurosis of the latissimus near the iliac crest, just behind Petit's triangle; the terminal branches are found over the gluteal region and as far down as the great trochanter. The internal branch has a course similar to that of the last thoracic nerve.

Variations in Course and Distribution.—The course and distribution of the nerves and vessels vary in different individuals to a certain extent, or may even be asymmetrically arranged on the two sides of the same subject. Race and sex have no relation to frequency of such abnormalities.

The causes of these variations are found in abnormal development during the early period of fetal life, which manifests itself in an irregular growth of the skeleton and muscles. The nerves affected are either those of one spinal segment and their immediate neighbors or the whole distal portion of the spinal cord, in which case the position of the nerves of the lower limb in relation to those of the lumbar region is affected. (Bardeen: "Study of the Abdominal and Border Nerves in Man," *American Journal of Anatomy,* 1901-1902, Vol. I, No. 2, p. 203.) The blood vessels adjust themselves more or less to these conditions and follow the larger nerves.

A somewhat abnormal arrangement of the vessels and nerves of the lumbar region is always to be expected in cases of a short or wanting XII rib. If the XII rib is not too short, the subcostal (XII) vessels and nerves vary little from the normal, but if the rib is so short that it resembles a transverse process of the first lumbar vertebra, then the vessels and nerves below the XI rib have a course and area of distribution almost identical to that of the subcostal, while those of the XII frequently resemble the I lumbar in their arrangement, the hypogastric branch arising from it.

The Five Types of "Border-Nerves."

12th thoracic	Type I 17%				
1st lumbar		Type II 2%	Type III 49%		
2d lumbar				Type IV 30%	
3d lumbar					Type V 2%

		12th Thoracic	1st Lumbar	
Type I, 17% of all cases examined	A	Hypogastric and Inguinal	Genito-Crural, communicating branch with 12th	10%
	B	Hypogastric and Inguinal	Genito-Crural, no com. br	12%
	C	Hypogastric	Inguin. and Gen.-Cru., com. br. with 12th	42%
	D	Hypogastric	Inguin. and Gen.-Cru., no com. br	22%
	E		Hypog. (com. br. with 12th), Inguin. and Gen.-Cru	14%

		12th Thoracic	1st Lumbar	
Type II, 2% of all cases			Hypogastric, Inguinal and Genito-Crural	

		12th Thoracic	1st Lumbar	2d Lumbar	
Type III, 49% of all cases	A	Hypogastric	Inguinal (common br. with 12th)		19%
			Genito	-Crural	
	B	Hypogastric	Inguinal (no com. br.)		19%
			Genito	-Crural	
	C		Hypog. and Inguin. (com. br. with 12th)		49%
			Genito	-Crural	
	D		Hypog. and Inguin. (no com. br.)		6%
			Genito	-Crural	
	E	1st Hypog	2d Hypog. and Inguin.		7%
			Genito	-Crural	

			1st Lumbar	2d Lumbar	
Type IV, 30% of all cases	A		Hypog. and Inguin		91%
			Genito	-Crural	
	B		Hypog. and Inguin	Genito-Crural	9%

The Five Types of "Border-Nerves."

Type V, 2% of all cases	12TH OR 13TH THOR.	1ST LUMBAR	2D LUMBAR	3D LUMBAR
	Hypogastric	Inguinal	Genito-Crural	

Any abnormalities are easily detected by an inspection of the superior lumbar trigonum.

In cases where the XII rib is wanting or very short the lumbar trigonum is somewhat longer than usual. Above and anteriorly it is not bordered by the tip of the XII rib, but only by the long and strong lumbo-costal ligaments (Figs. 5, A and B). The nerves and vessels of the short XII rib run on the inner side of this ligament, not in the direction of the rib, which stands out almost at right angles to the spine, but parallel to those of the XI rib, slightly diverging from them as they proceed downward, across the upper half of the trigonum. An incision should, if possible, be made below these vessels and nerves, as their upper course is about on the same level with the pleura.

A clear insight into the relative frequency of the different variations may be gained by a study of Charles R. Bardeen's table.

The three nerves, ilio-hypogastric, inguinal, and genito-crural, are termed "border nerves," and there are five different types according to which they may be arranged. (See page 27.)

VERTEBRAL COLUMN AND RIBS.

The vertebral column, as seen in profile, presents several curves, a forward curve in the cervical region, a backward one in the thoracic, a forward one in the lumbar, and again a backward curve in the sacral region. While the thoracic and sacral curves are already marked in the young fetus, those in the cervical and lumbar regions do not develop until after birth. From the VIII thoracic vertebra down to the II lumbar the vertebral column has a forward direction. With the body in the erect posture, it runs at an angle of about 15 degrees to the perpendicular, and the kidneys, being situated between the levels of the XI thoracic and III lumbar, lie just at the lower half of this anteriorly directed portion of the vertebral column. This angle is subject to many variations and changes, even in the same individual; i. e., with the body standing erect in military position the angle is small, and becomes smaller if the thorax be bent forward. The angle is increased with the body in an easy relaxed standing position, especially in women who wear corsets which lace below the level of the last rib. The position of the ribs is more

or less dependent upon the position of the vertebræ, and if, as we shall see later, the latter has a marked lumbar curve, we find that the lower ribs, together with the muscles, especially the psoas and quadratus, but also the broad abdominal muscles, form capacious niches for the kidneys.

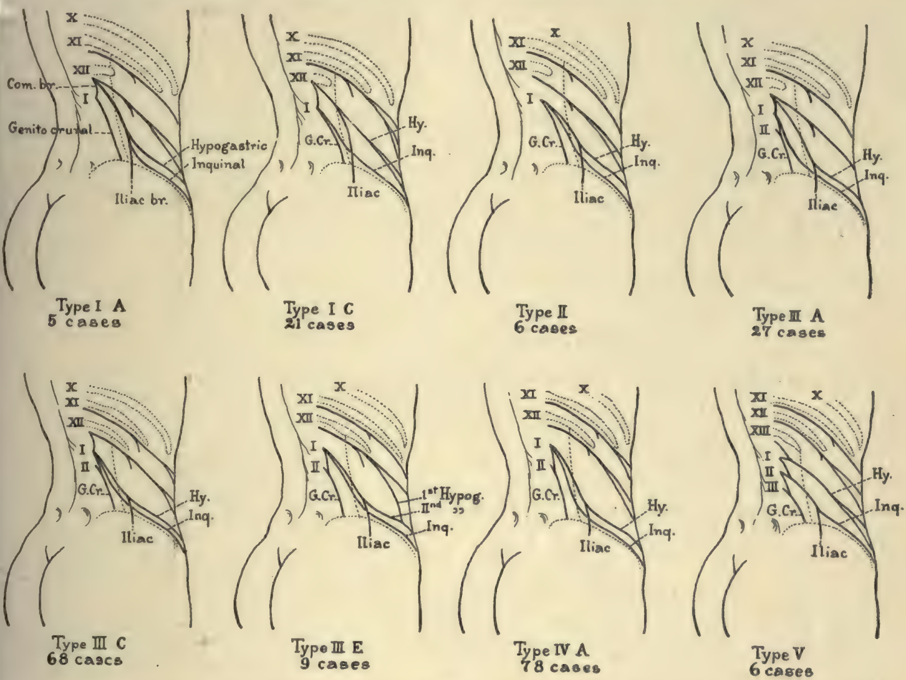


Fig. 15.—Diagrams Showing the Distribution of the Last Thoracic and the Lumbar Nerves. The frequency of the different types is indicated. (Bardeen's table modified.)

The ribs which come in contact with the kidneys are the XI and XII and their anatomical characteristics should be noted. Unlike the other ribs, these have no cartilaginous connection with the sternum, but end free in the lateral abdominal wall. They are thin and elastic bones which run downward and outward parallel to the other ribs, in length variable, and on their outer end a small cartilaginous prolongation. On section they are oval, but somewhat sharpened below, forming on the XI an indistinct subcostal groove lodging the vessels and nerves. This, however, is lacking on the XII rib. The average length of the XII rib is 12 cm.; it may, however, be as long as 18 or 20 cm. Frequently it is quite short, even less than 3 cm., so palpation does not reveal its presence. If it is shorter than 5 cm., it is as a rule broad and directed

transversely, resembling the transverse processes of the lumbar vertebræ (Fig. 5 B). A short XII rib lies entirely within the walls of the pleural cavity, while a long rib may reach with its outer third or fourth below the pleura to the wall of the abdominal cavity. The XII rib may be absent altogether, but this is said to be comparatively rare.

These facts prove the mistake of supposing that the last palpable rib is the XII. Always count from above down and make sure of the position of the XII rib.

If there are thirteen and the supernumerary one is thoracic, not cervical, it is, as a rule, very short and appears attached to the transverse process of the first lumbar vertebra; rarely is it associated with a thirteenth thoracic vertebra. It may be uni- or bilateral.

DIAPHRAGM AND PLEURA.

The Diaphragm (Fig. 7).—The diaphragm is the roof of the abdominal cavity, which it separates from the organs of the thorax. Its attachment to the thorax is mostly fleshy; the central portion is tendinous. Beginning anteriorly, short fibers arise from the ensiform cartilage; while, laterally, longer and more curved fibers take their origin from the inner surfaces of the VI or VII lower ribs. Then come a few fibers, which interlace with the M. transversalis, and finally long ones, which are attached to the ligamenta arcuata and to the lumbar vertebræ. The diaphragm is supplied by the two phrenic nerves and by the phrenic plexus of the sympathetic. The two phrenic arteries come from the aorta, celiac axis, or renal arteries.

The diaphragm forms two dome-like elevations, which are occupied by the liver on the right and by the kidney, spleen, stomach and left lobe of the liver on the left. The right cupola is, as a rule, 1 to 3 cm. higher than the left, but this condition may not infrequently be reversed. On the posterior portion the lower limit of the pleural cavity is along a line about 2½ cm. above the muscular attachment of the diaphragm to the ligamenta arcuata.

In a state of contraction the roof of the diaphragm becomes flattened; more so on the left side, as the flaccid stomach offers less resistance than the firm right lobe of the liver. The central portion descends least, being more firmly anchored through its connection with the pericardium. Complete expiration causes the dome of the diaphragm on the right side to be on a level with the posterior portion of the VII rib; on the left side with the IX rbi. Deep

inspiration is associated with diaphragmatic contraction; the level of the dome descending from 3 to 5 cm., while at the same time the lower ribs are somewhat elevated.

Of the diaphragm those portions concern us most which are attached to the XII rib and ligamenta arcuata Halleri, and the adjoining part of the costal portion. As Figure 7 shows, the muscular fibers of the diaphragm at this region are not perfectly regular in their arrangement, as between the bundles arising from the median arch of the ligamenta arcuata and those coming from the lateral arch there are places almost or entirely devoid of muscular fibers. Lateral to this region there is another similar area. The diaphragm consists at these places of a thin layer of areolar tissue, lined on the abdominal side by the peritoneum and on the thoracic side by the pleura. The pararenal or subperitoneal fat which fills the entire space between the fascia retrorenalis and the muscles of the lumbar region may in these places be continuous with the subpleural cellular tissue and abscesses developing in the pararenal fat may sometimes break at these points into the pleural cavity. Herniæ may also protrude through these openings. (See Fig. 39.)

The Pleuræ (Figs 7 and 16).—The pleuræ are two smooth, delicate membranes which cover the lungs and are reflected over the inner surface of the thoracic cavity. As the lungs in normal condition lie close to the walls of the thorax, there is but little space between the two surfaces of the pleura. The right pleura is separated from the left by the mediastinum.

The posterior reflection of the costal portion of the parietal pleura over the upper surface of the diaphragm is of considerable interest in renal surgery, as it is situated very near the region of the lumbar incision. The line of the pleural reflection begins along the lateral surface of the XII thoracic vertebra at the level of the origin of the XII rib or slightly below, passing obliquely downward and outward. It is crossed by the XII rib at a distance of 5 to 8 cm. from the middle line (Fig. 16 A). It then gradually rises and when it has reached the lateral portion of the thorax it is on the right side in the vicinity of the IX rib, or about 6 cm. above the lower margin of the thorax, while on the left it is found somewhat lower, being on a level with the X rib. The pleura may pass higher or lower than here described, but these instances are quite rare. The diaphragmatic portion of the pleura lies for some distance upward in close contact with the costal portion, as the lung, even in deepest inspiration, never descends as low as the line of pleural reflection. About 4 cm. of the XII rib lie above the level of the pleura, while the outer portion of the rib extends below it and forms a part of the abdominal wall. According to the length of the XII rib this abdominal end

varies in extent. It may be anywhere from two-thirds to one-quarter the whole length, or may be entirely wanting in cases where the XII rib is short (see Fig. 16 B). Irrespective of the length of the XII rib, the lower limit of the pleural reflection remains the same.[1] It is, therefore, important to determine whether the last palpable rib be the XI or XII, which can only be accurately accomplished by carefully counting them from above downward.

The relation of the lumbo-costal ligament to the pleura is worth studying

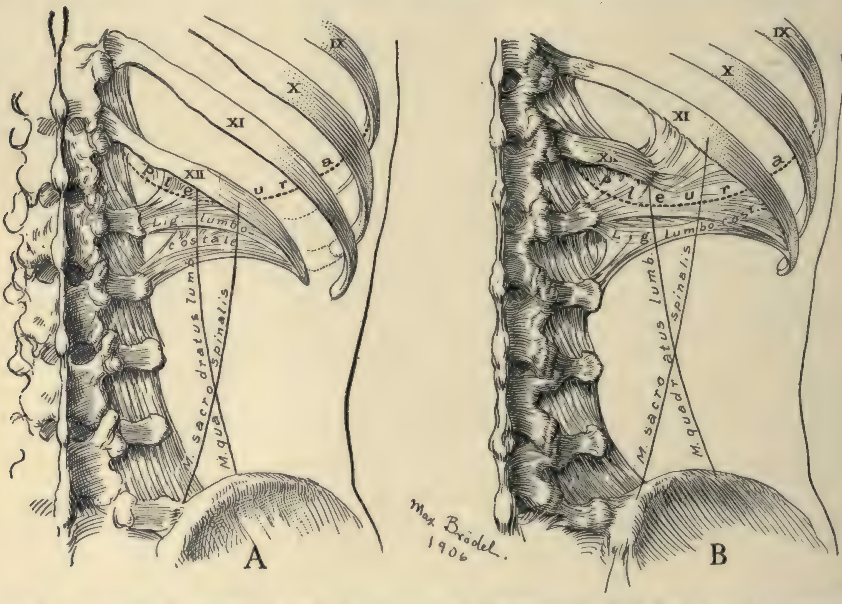


Fig. 16.—Diagrams Showing the Relation of Pleura to XII Rib and Ligamentum Lumbo-costale. A, normal rib; B, rudimentary rib.

because it is this ligament more than any other structure which, because of its position, protects the pleura from injury during an operation.

There are two portions of this ligament, an upper one attached to the transverse process of the I lumbar vertebra, and a lower one running to the corresponding part of the II lumbar vertebra. These median attachments are constant in all cases, both with a long and with a short XII rib; laterally the ligament is connected with the XII rib if the latter is of sufficient length, otherwise with the XI rib. In the depth the lumbo-costal ligament is strengthened by the fibers of the ligamentum arcuatum Halleri, which runs approximately in the same direction. Combined, these form a very strong band just below the line of the pleural reflection; the pleura never extends below them, and

if they be left intact in the course of a renal incision no danger of injuring the pleura need be feared. If need be, the bundles coming from the transverse process of the II lumbar vertebra may be sacrificed, but the upper portion, i. e., that attached to the transverse process of the I lumbar vertebra, should never be cut.

If necessary to resect the last rib, a subperiosteal removal will diminish any danger of injuring the pleura.

CHAPTER II.

THE RELATION OF THE KIDNEYS TO THE NEIGHBORING ORGANS.

A. TOPOGRAPHY OF THE KIDNEYS FROM WITHOUT.

1. Relation of the Kidneys to the Vertebræ and Ribs, to the Crest of the Ilium, Diaphragm and Pleura, and to the Muscles of the Back.—Relation to Vertebræ and Ribs.—The upper pole of the kidneys is found at a level with the middle or the lower part of the XI or XII thoracic vertebra, while the lower pole reaches as far down as the lower portion of the II and sometimes to the III lumbar vertebra. An extension outside these points must be considered as abnormal; i. e., an upper pole at the X vertebra or a lower pole below the III lumbar. In the female the kidneys are about one-half a lumbar vertebra lower than in the male.

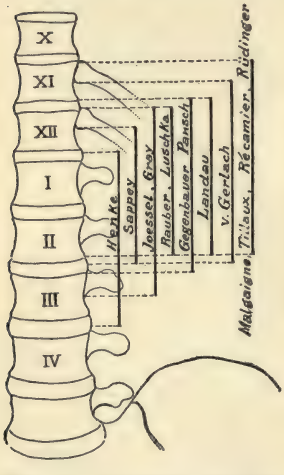


Fig. 17.—Position of Kidneys in Relation to Vertebral Column as Given by Various Authors. Note wide variations. (After Helm.)

A glance at Figure 17 shows how much writers vary in their statements as to the position of the kidneys, not surprising if it is remembered how much the relation of the kidney to the vertebræ varies in different subjects. It depends greatly upon the size of the kidney, height of the vertebræ, differences on the two sides of the same individual, and also upon sex and age. The personal equation of the examiner also plays an important rôle.

(a) Differences between the Two Sides of the Body.—The right kidney is, as a rule, situated at a slightly lower level than the left; an arrangement not infrequently reversed, and Pansch states the lower position of the right kidney to be not a regular but only a frequent occurrence; for in certain groups of cases observed by him every third cadaver showed the left kidney lower.

Sappey notes in the majority of cases both kidneys to be situated "à peu

près au même niveau." Helm tells us he found 57 times the right kidney lower, 17 times the left kidney lower, and 13 times both kidneys on same level. In a majority of cases the low position of the left kidney seems acquired, and a few are to be considered as arrested in ascent during fetal life.

The differences between the position of the left and right kidneys vary from 1 to 8 cm. and more, a difference of 1 to 2 cm. being the most frequent.

The cause for the lower position of the right kidney is found in the fact that the right lobe of the liver being so much larger than the left arrests the ascent of the organ on that side.

This is proved by the fact that in the human fetus, in the newborn, and in the higher animals, where the left lobe of the liver is relatively large, the kidneys are found on the same niveau, or the left is even lower. The low position of the left kidney is also seen in cases of situs transversus lateralis, where the left lobe of the liver is the larger.

So it is not pressure of the liver in the adult which forces the kidney down, but the large size of the right lobe, checking the ascent of the right kidney.

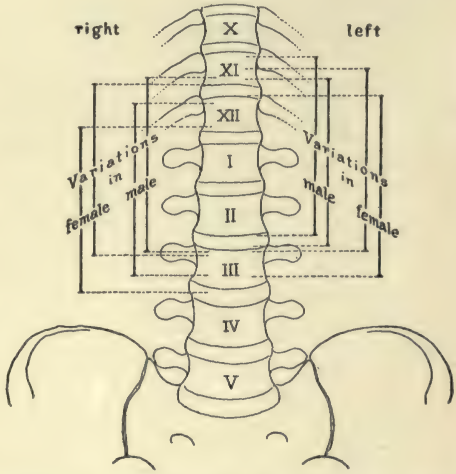


FIG. 18.—VARIATIONS IN POSITION OF KIDNEYS. Inside lines, male; outside lines, female.

(b) Variations in the Position of the Kidney According to Sex and Age.—The kidneys are normally found at a somewhat lower level in the female. This amounts to about the height of half a lumbar vertebra, and in women an abnormally low position of one or both kidneys is also much more frequent. The accompanying diagram (Fig. 18) illustrates the average position of the kidneys in the two sexes.

The kidneys in children are situated at a decidedly lower level, especially during the first few years. The cause for this, in the first place, being the relatively large size of the kidneys (twice to three times as large as in the adult); the greater extent of the liver; and, finally, the relative shortness of the lumbar region in childhood.

The median border of the kidney is situated in front of a line connecting

the tips of the transverse processes of the lumbar vertebræ. The upper portion of the kidney in its normal position is covered by the last two ribs, on the left side to a greater extent than on the right. Occasionally, the upper pole may reach as high as the X rib.

The relation of the kidney to the XII rib is very variable; firstly, because the rib itself is subject to so many variations as to length and position; and, secondly, because of the variations of the position of the kidney itself. The last rib may be very short or even wanting, and, if short, it runs horizontally, similar to the transverse processes of the lumbar vertebræ.

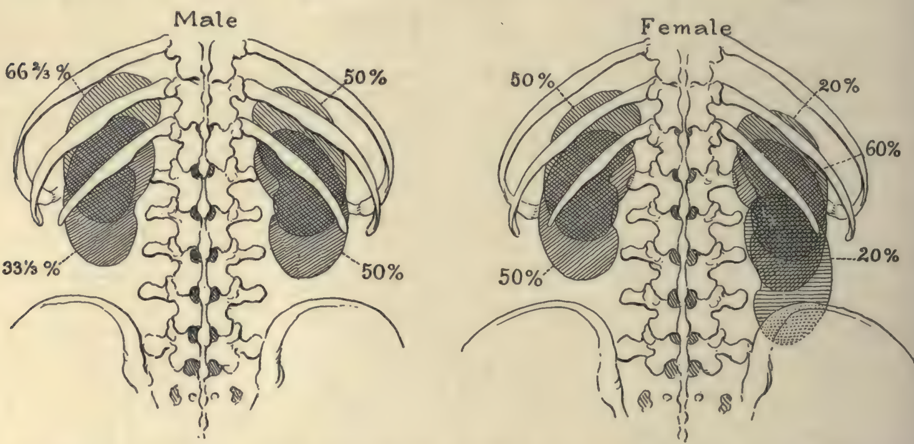


Fig. 19.—Diagrams Showing Positions of Kidney, Male and Female. The percentages indicate frequency of occurrence. Note the low position of right kidney in the female.

Recamier examined and measured the XII rib in 50 cadavers, finding:

27	times	a length	of	14-13	cm.
36	"	"	"	12-10	"
13	"	"	"	9-7	"
10	"	"	"	6-5	"
14	"	"	"	4½	"

Ribs of 5 cm. length or less would have to be considered as not palpable.

If the XII rib is of usual length and the kidney in its usual position, the rib runs obliquely down at an angle of 45 degrees over the central portion of the kidney, dividing it topographically into a thoracic and an abdominal part. The division is generally such that two-fifths are thoracic and three-fifths abdominal (Fig. 20). A division into halves, however, is also frequent.

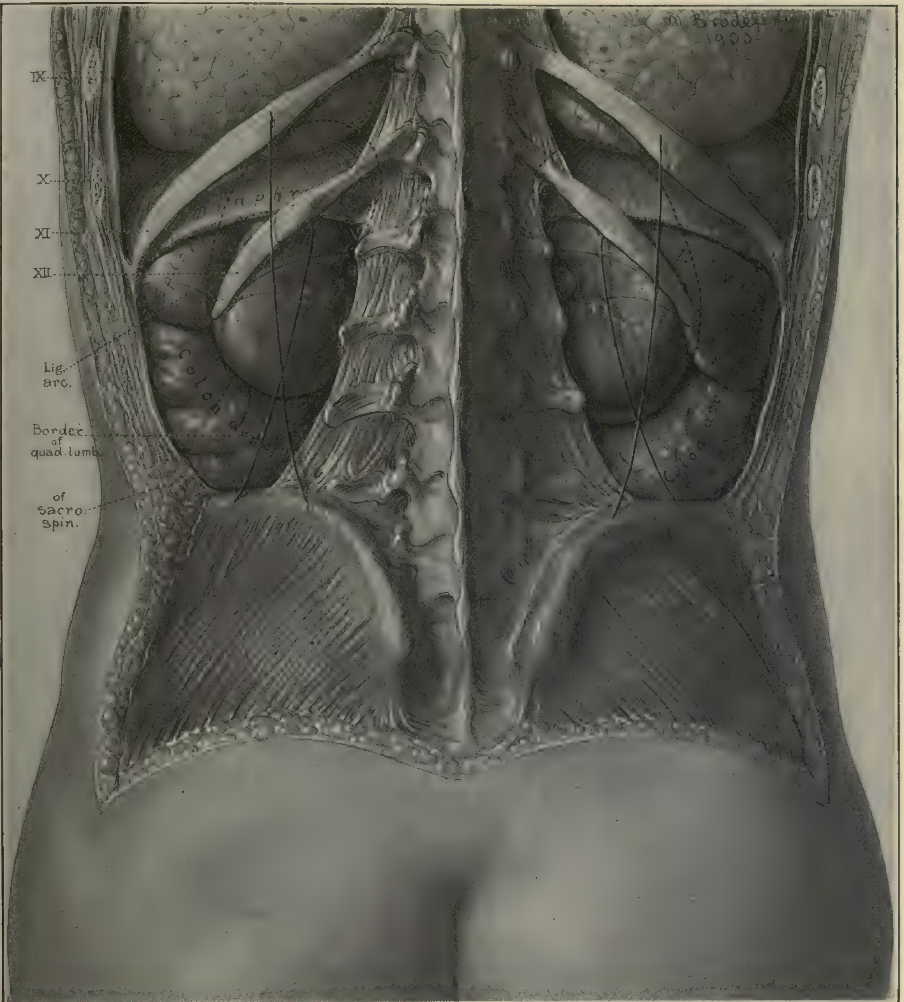


FIG. 20.—POSTERIOR VIEW OF BODY, INTEGUMENT AND MUSCLES REMOVED. Note relations of viscera and lines indicating outer borders of M. sacro-spinalis and M. quadratus lumborum.

Figure 19, prepared from statistics given by Helm, gives a good idea of the relative frequency of the high and low position on both sides and in both sexes. If the last rib is short and horizontal, the abdominal part of the kidney is two-thirds to four-fifths of the whole organ. The pleura extends in such cases below the XII rib (Fig. 21).

Relation to Crest of Ilium.—The relation of the normal kidney to the crest of the ilium is likewise variable. The usual distance between the lower pole of the kidney and the crest is about 5 cm., but a variation is not abnormal. Again, much depends on the length of the kidney and the number and height of the lumbar vertebræ. The right kidney, on account of its lower position, comes as a rule about ½ cm. nearer the crest than the left, yet, as the right kidney is frequently somewhat shorter, though thicker, than the left (5 mm.-1 cm.), the lower poles of the two are sometimes at the same level. A table, prepared from the statistics given by Helm, shows this relation:

The distance between the lower pole of the kidney and iliac crest varies

in men,	On the right side from 0 (10%) -3.5 cm.	left side from 2½-5.5 cm.
in women	On the right side from 0 (40%) -3 cm.	left side from 0 (10%) -4 cm.

Of course, in kidneys pathologically enlarged the lower poles may frequently extend to or lie a considerable distance below the crest.

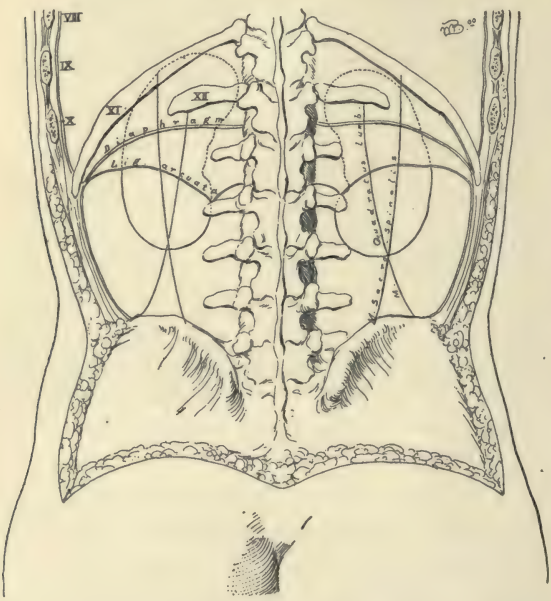


Fig. 21.—Same as Fig. 20. In cases with rudimentary twelfth rib.

Relation to Diaphragm.—The diaphragm has quite a definite relation to the kidneys, as the upper poles of both kidneys lie in contact with it and it covers the right kidney to a less extent than the left. About one-third of the left and one-fourth of the right are in contact with the diaphragm, so the direct influence of the respiratory movements is more marked on the left.

As well known, the diaphragm has areas devoid of or sparsely covered with muscle (see Fig. 7), and, as such an area lies near the upper pole of the kidney,

here may exist a close contact between the pleura and the posterior surface of he kidney. Such a condition is more pronounced when the XII rib is short.

This weak diaphragmatic space is on the right side covered and protected at its apex to a certain degree by the right lobe of the liver, while on the left the kidney lies directly against it. This fact may explain why perirenal abscesses are more liable to break through into the pleural cavity on the left side.

As the two adrenal bodies lie close to the upper poles of the kidneys, they are likewise covered by the diaphragm.

Below and medianward the kidneys rest against the quadratus lumborum, the psoas, and farther up against the pillars of the diaphragm. As the psoas and quadratus increase in width and thickness below, they form a cushion for the kidney, which is still more perfected by an accumulation of the para- and perirenal fat below the kidney. The lateral border of the kidney extends beyond the lateral border of the quadratus, and its lower lateral portion rests against the transversalis fascia in the region of the superior lumbar trigonum.

Relation to the Pleura.—I need only here recapitulate that the pleural reflection is found at about a horizontal line through the middle of the XII rib, and if we have to deal with a case of short or missing XII the pleura is found $1\frac{1}{2}$-$2\frac{1}{2}$ cm. below that rib (see Fig. 16). From this it follows that the pleural line divides the kidney into two portions. On the left side about one-half of the kidney is below the pleural line, while on the right side two-thirds are below.

We know that the lumbo-costal ligament and the ligamenta arcuata Halleri form a strong natural protection of the pleural reflection, especially in cases of short or missing XII rib. These ligaments run approximately parallel to the pleural reflection, $\frac{1}{2}$ cm. below it, and should be spared in renal operations, or at least those fibers of the lumbo-costal ligament that come from the transverse process of the I lumbar vertebra.

The resection of a rib, if absolutely necessary in the course of an operation, must be done subperiosteally, utilizing the periosteum as a means of protection of the slightly resistant pleura. After the XII rib has been removed the entire kidney is exposed.

2. Relation of Kidneys to Liver, Spleen and Large Intestine as Seen from Behind.—Dissecting off the muscles of the back and removing the posterior layer of fascia covering the kidneys, we find they stand in a definite relationship to the liver, spleen and large intestine.

Figure 22 shows the entire abdominal viscera removed *en masse* and viewed from behind.

While the left kidney is on a slightly higher level and visible over its entire posterior surface, the right kidney reaches somewhat lower and its upper pole

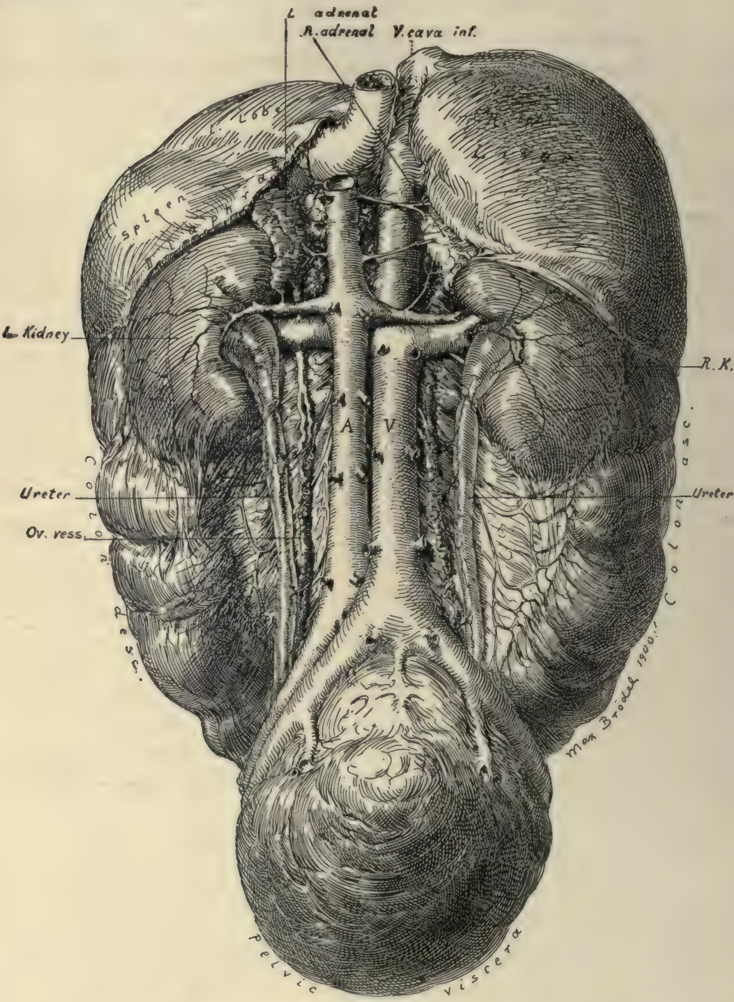


FIG. 22.—DISSECTION OF ENTIRE ABDOMINAL AND PELVIC VISCERA, *EN MASSE*, VIEWED FROM BEHIND.

appears to a certain degree covered by the liver. This, however, is not the case in the majority of instances and, though it is by no means an infrequent occurrence, the rule is an arrangement shown in Figure 23, i. e., the liver covering

only the anterior surface of the kidney. Returning to Figure 22, the relation of the kidneys to the large vascular trunks of the abdomen and to the large intestine is clearly given, also that of the ureters, as seen from behind. In

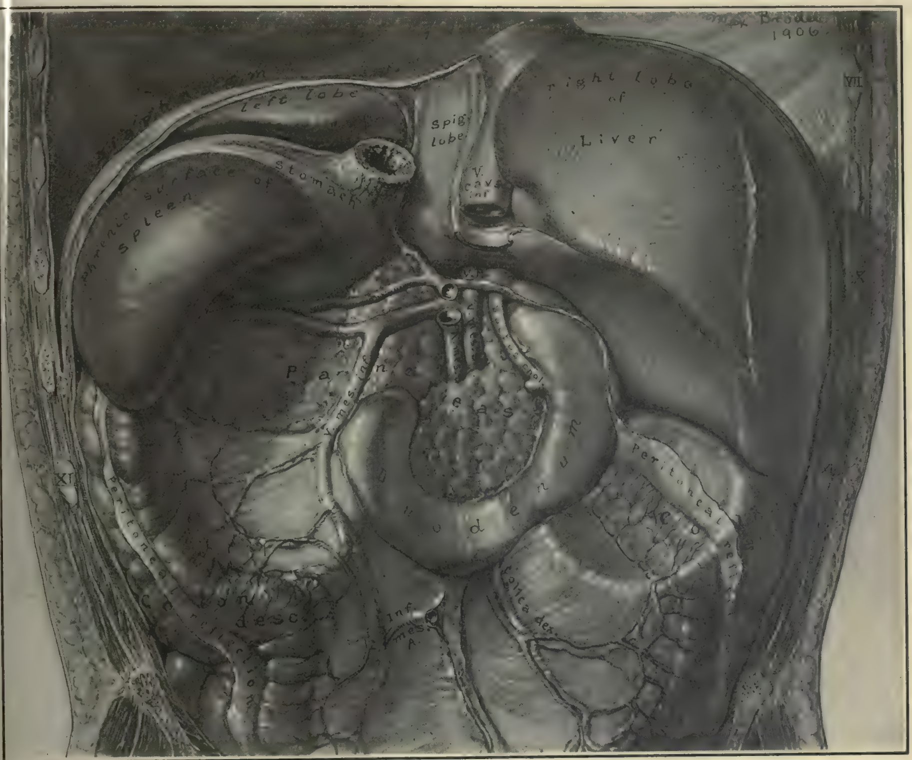


Fig. 23.—Abdominal Viscera from Behind, Kidneys Removed, Showing Areas of Contact with Other Organs.

this particular instance we have to deal with a moderate degree of hydronephrosis and hydroureter, but this rather adds to the clearness of the picture.

Removing the kidneys, together with the large vessels of the abdomen, we demonstrate the beds of the kidneys as formed by their areas of contact with the abdominal viscera (see Fig. 23). The bed of the right one is bordered above and laterally by the liver, below by the ascending colon; while that of the left kidney is bordered above and laterally by the spleen, below by the descending colon. Medianward to the hollows are the descending and ascending portions of the duodenum. During life the impressions of the kidneys

on the different organs of the viscera, and the corresponding flattenings on the surfaces of the kidneys, are hardly perceptible; they are mainly due to post-mortem changes of the organs, and fixation through hardening fluids.

As soon as one organ yields, another takes its place, thereby changing its form and position. The intestines especially possess this adaptability to a re-

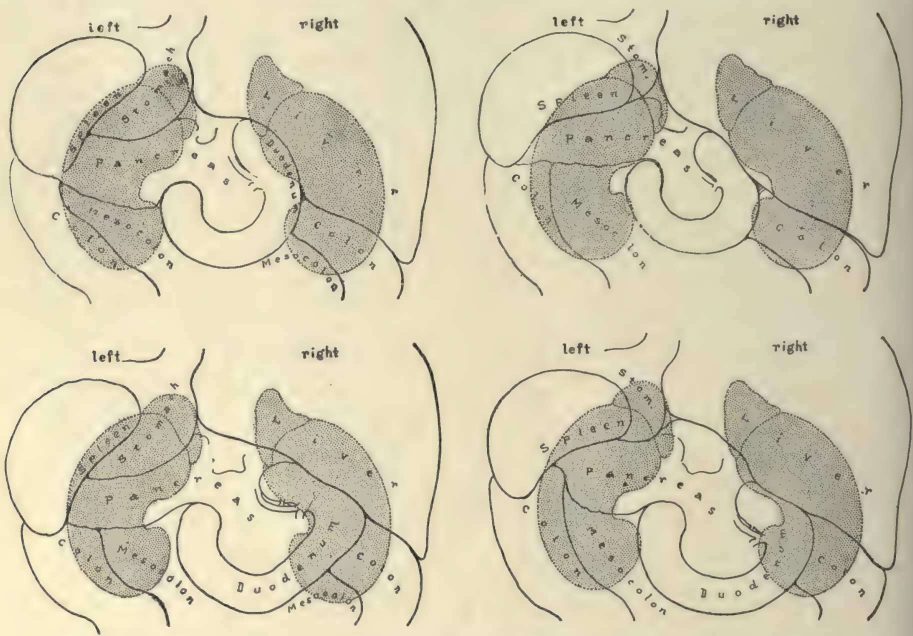


FIG. 24.—FOUR DIAGRAMS, SHOWING THE PRINCIPAL VARIATIONS OF AREAS OF CONTACT BETWEEN THE KIDNEYS AND OTHER ORGANS.

markable degree, likewise the liver, which fills the gaps and corners of the upper abdominal cavity like a mass of soft clay.

Although these impressions do not exist in life, it is very interesting to study them, as they afford, next to the method of frozen sections, the best way to determine the relative positions of the organs.

A glance at Figure 23 will teach more topography than an elaborate description. Figure 24 shows the most common variations of the areas of contact.

RIGHT KIDNEY.—The upper and outer extremity of the right kidney lies closely against the liver, with the peritoneal cavity between. The extent of this contact depends upon the position of both organs. A lace-liver in its low position would cover almost the entire anterior surface of the kidney, while

a movable kidney in low position would not come in contact with the liver at all. Normally the liver covers about the upper third of the kidney and the whole adrenal body except its lowest corner, which comes in contact with the duodenum and pylorus.

The middle portion of the kidney lies against the hepatic flexure of the colon, the mesial portion of which has no peritoneal covering (peritoneal reflection over the kidney and colon indicated on the drawing). The colic vessels run along the median border of the colon and lie closely against the lower pole of the kidney. Between the lowest portion of the kidney and the loops of small intestine is the mesocolon with its vessels, consisting of three layers of peritoneum, separate in the fetus but fused in the adult.

The ascending colon lies farther forward and medianward than the descending. Its angle with the transverse colon is more than 90 degrees. The transverse colon continues to ascend more or less, bringing the splenic flexure in the first place to a higher level than the hepatic flexure, and producing also a smaller angle with the descending colon. The hepatic flexure of the colon comes to lie closer to the lower pole and farther anterior to the kidney than the splenic flexure, which crosses the upper pole and hugs the lateral border of the left kidney.

The inner surface of the right kidney rests against the descending portion of the duodenum and the head of the pancreas. The area of contact is larger in the female than in the male, as the result of lacing. There is no peritoneum between them. The common bile duct lies directly against the median border of the upper pole and the adrenal. Between them at the upper portion is the lesser peritoneal cavity; below, the duct rests directly upon the hilum of the kidney. The lower pole at the median border is, as above stated, again covered by peritoneum, three layers (parietal peritoneum and two layers of mesocolon), against which rest parts of the jejuno-ileum.

Left Kidney.—The upper and outer extremity of the left kidney lies against the spleen. This renal surface of the spleen is a narrow area between the phrenic and gastric surfaces of that organ. There is peritoneum between the spleen and the kidney; but only a small part of the outer upper portion of the kidney is so covered. The peritoneum arises from the hilum of the spleen and is reflected over the kidney to form the posterior layer of the lieno-renal ligament. As the spleen varies so much in size, no definite measurement can be given of the extent of the splenic surface over the kidney.

Medianward to the splenic surface of contact comes the gastric surface. There is the peritoneum of the lesser peritoneal cavity between the two organs. Between the inner portion of this gastric surface and the upper pole lies the

adrenal body. Transversely across the middle of the kidney is the area of contact with the tail of the pancreas. Along its upper border run the splenic vessels. There is no peritoneal covering between the two organs.

The lower half of the left kidney lies along its lateral border in contact with the splenic flexure of the colon and a part of the descending colon; medianward, it is covered similarly to the corresponding portion of the right kidney by the mesocolon and its vessels. The colon on the left side reaches farther both laterally and upward than that on the right. It crosses the left kidney obliquely either in its upper third, middle, or (rarely) at or below the lower pole. In the fetus the mesocolon is free and has two layers of peritoneum. The colon is likewise free in its entire length. The parietal peritoneum covers the entire lower portion of the kidney (Fig. 25). Later the two layers of peritoneum of the mesocolon and that of the posterior portion of the colon become adherent to and completely fuse with the parietal peritoneum, thus producing an appearance as though the parietal peritoneum were reflected over the lateral border of the colon (Fig. 25). Along the hilum of the left kidney pass the inferior mesenteric vein and, below, branches of the A. colica sinistra, coming from the inferior mesenteric artery (Fig. 23).

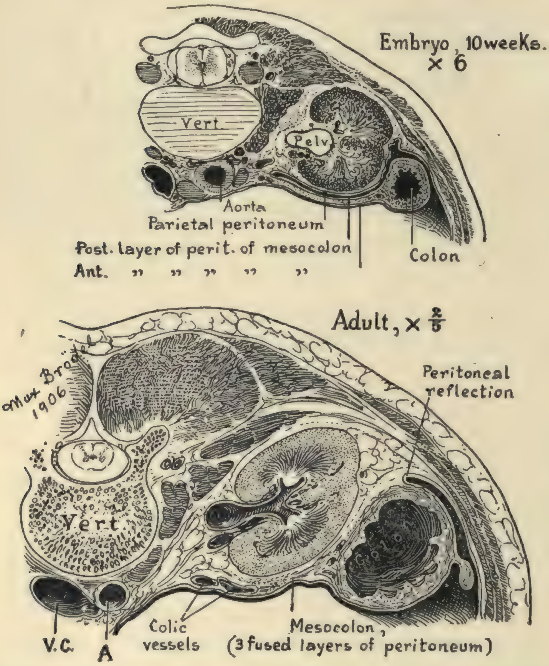


FIG. 25.—CROSS SECTIONS OF EMBRYO AND ADULT ILLUSTRATING THE RELATION OF THE MESOCOLON TO THE LEFT KIDNEY. The three separate peritoneal layers in the embryo are fused into one in the adult.

The terminal part of the duodenum and a portion of the jejunum are situated near the lower portion of the hilum. Convolutions of the upper portion of the small intestine are in contact with the lower pole of the kidney, from which they are separated by the mesocolon and its vessels.

If a kidney descends, its place is occupied by the abdominal organs, which are situated above and anterior to it. In the case of a right kidney, the liver, colon and duodenum would take its place, while a descended left kidney would be replaced by the spleen, pancreas, stomach and colon. The spleen may in such a case descend and shift so much toward the vertebral column, lodging in precisely the same place the kidney should occupy, that it may at an operation be mistaken for a kidney.

B. TOPOGRAPHY OF THE KIDNEYS FROM WITHIN.

In the abdominal cavity the kidneys are situated outside the peritoneal cavity in a retroperitoneal funnel-shaped space at each side of the vertebra. These spaces or niches in which they lie embedded are formed by the psoas (median), broad abdominal muscles (lateral), quadratus lumborum (posterior) and the diaphragm (above). In front and laterally the kidneys are covered by peritoneum and by the extra-peritoneal surfaces of the following organs situated in the upper abdominal cavity: both adrenals, ascending colon, duodenum, descending colon and pancreas.

Axes of the Kidney.—The position of the kidneys in these niches or pockets is of sufficient interest to merit description.

Horizontal Axis.—A horizontal section of the body through the level of the transverse process of the I lumbar vertebra cuts the kidneys through the region of the hilum, and they appear, roughly speaking, as two oval bodies whose topographical axes incline forward toward the median line of the body to meet one another at an angle varying from 60 degrees to 120 degrees. As a rule, the angle is about 80 degrees to 90 degrees, as shown in Figure 26.

There is also an anatomical axis of the kidney, dividing the organ into two secretory, independent halves, which runs through the center of the pelvis toward the middle of the cortex between the anterior and posterior pyramids. This axis meets its fellow of the other side at a point much farther back.

In the fetus the anatomical is often identical with the topographical axis, both running, as a rule, at right angles to the middle line of the body. The kidneys are then directed not obliquely backward, as in the adult, but laterally (Fig. 26), a position largely due to the form of the pockets in which they lie, these being very shallow, owing to the flattened shape of the vertebral bodies, the undeveloped spinous processes and the direction of the ribs, which leave the vertebral column at almost right angles to the middle line. These

characteristics of the fetal skeleton give the sacro-spinalis, psoas and quadratus a more flattened character.

As the vertebral column, ribs and muscular structures develop, the anterior margin of the vertebral bodies pushes forward, the ribs begin to follow

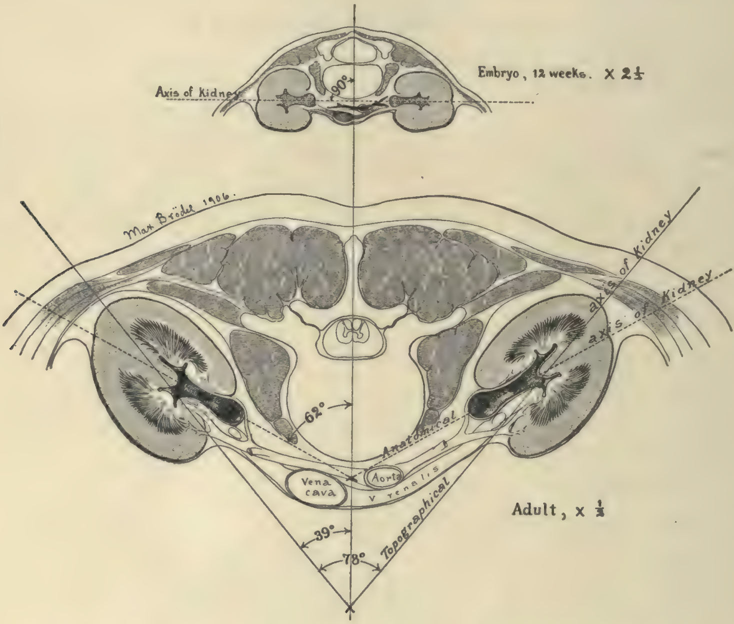


FIG. 26.—DIAGRAMS SHOWING THE DIFFERENCE OF THE HORIZONTAL AXIS IN THE FETAL AND ADULT KIDNEY. While in the fetus the anatomical and topographical axes coincide, there is considerable difference in the adult.

a more backward curve, while the psoas, quadratus and sacro-spinalis recede at the same time and the whole surface against which the kidney comes to lie begins to take a backward slant, thus bringing about the converging appearance of the topographical renal axes as shown in the figure. This rotation backward is associated with a shifting of the posterior portion of the kidney from the anterior portion, so the former overlaps the latter at the lateral border, and the hilum is found receding toward the posterior surface.

The direction of the axes is by no means always symmetrical (Fig. 27). On the contrary, there is in most cases a difference between the angles of the two axes with the median line. That of the right kidney is generally from 5 degrees to 10 degrees larger than that of the left, occasionally as much as

25 degrees, and even more. In other words, the angle of the axis with the median line may vary from 25 degrees to 70 degrees, because the right renal niche remains in a large proportion of cases more shallow than the left.

Our terms: anterior surface, lateral border, etc., although convenient, are not topographically correct. The anterior surface really points more laterally than anteriorly; the lateral border is, in fact, the posterior margin of the

Fig. 27.—Diagram Showing Frequent Asymmetry of Topographical Axes of Kidneys, Due to Deeper Niche on Left Side.

kidney, while the posterior surface is directed more medianward than posteriorly.

Vertical Axis.—(1) *Viewed from the Front.*—In the adult they are by no means parallel to one another. Owing to the funnel-shaped form of the pockets in which the kidneys lie embedded, the lower poles are farther apart ($3\frac{1}{2}$ to 4 cm. from median line) than the upper poles ($2\frac{1}{2}$ cm. from median line). The psoas muscle with its thick belly is the main cause for the more lateral position of the lower poles. The liver and spleen perhaps affect the upper poles, which are pressed by them medianward into the deepest portion of the niches.

The vertical axes (see Fig. 30) form, as a rule, an angle of 13 degrees to 15 degrees with the median line. A slight degree of asymmetry is often noticeable, especially in cases of scoliosis, even though this be insignificant. It is the angle of the right axis with the median line which generally shows an increase, while the opposite is decreased.

It is interesting to study the shifting of the vertical axes of the kidney

from the position they have in the fetus when the ascending kidney has reached the adrenal body and begins to develop in size. The latter is then larger than the kidney, occupying relatively the same position which the upper pole of the kidney is to fill in the adult. The growing kidneys must, therefore,

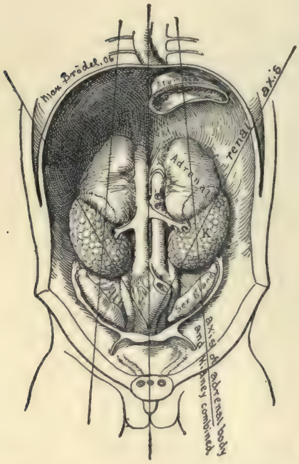


FIG. 28.—DIAGRAM SHOWING VERTICAL AXES OF KIDNEYS AND VERTICAL AXES OF ADRENAL GLANDS AND KIDNEYS TOGETHER IN EMBRYO. ABOUT TEN WEEKS OLD. × 5.

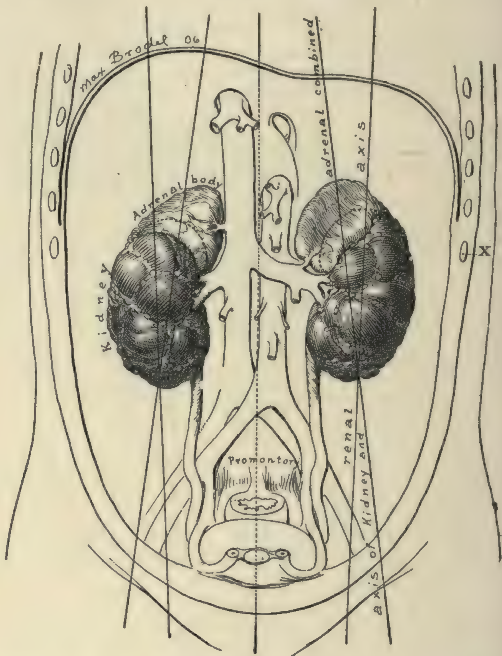


FIG. 29.—SAME AXES AS SHOWN IN LAST FIGURE. Note here in newborn babe how much more perpendicular the renal axes are.

develop in a more lateral direction, which causes their vertical axes to diverge above from the median line (see Fig. 28) and meet, not above, as in the adult, but below. Taking the kidney and adrenal for one organ, the axis of the two combined passes almost in the same direction as the renal axis in the adult, thus demonstrating the shape of the renal niches to be approximately the same.

In the newborn the vertical renal axes pass almost perpendicularly (Fig. 29). The adrenal bodies are considerably smaller in relation to the size of the kidneys, thus permitting the kidneys to assume a more perpendicular position. The combined axis of the adrenal and kidney (imagined as one organ) again remains in the same position as in the 10 weeks' fetus and in the adult.

(2) Viewed from the Side.—In a side view of the body the vertical

axes of the kidney also run by no means parallel to the vertical axis of the body, but take a backward slant (Fig. 32), due in the first place to the lumbar curve of the vertebral column and also to the backward curve of the ribs. The

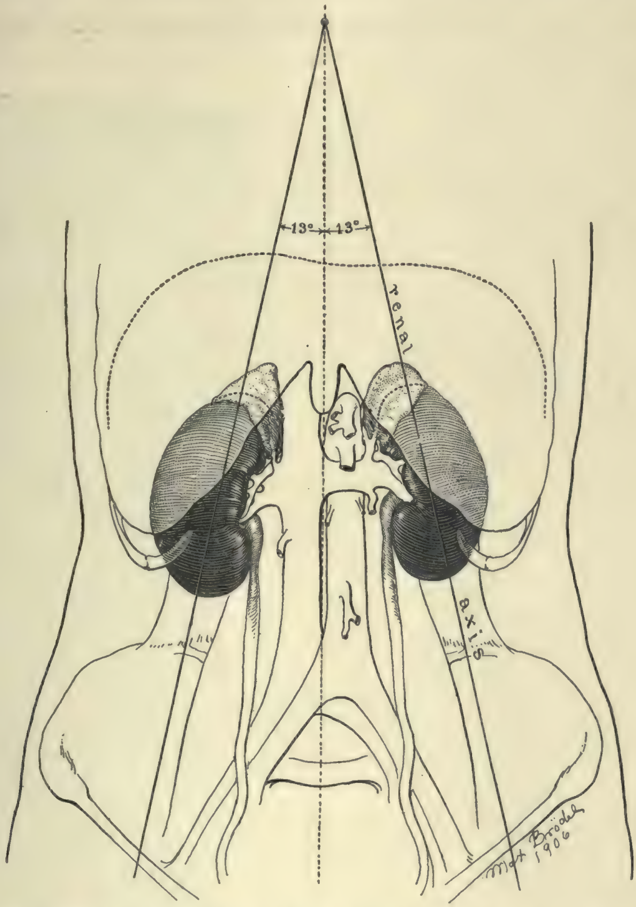


FIG. 30.—THE VERTICAL RENAL AXES IN THE ADULT. Note how the axes now converge upward in place of downward.

iliac crest remains in relation to them as a comparatively fixed ridge. The muscular structures forming the bolster against which the kidneys rest follow that backward slant indicated by the bony structures, and the kidneys, in consequence, lean with their upper poles in a posterior direction.

In the fetus this renal axis runs more nearly parallel to that of the body

(Fig. 31), a difference resulting from similar causes, as the changes of the other axes. The vertebral column is comparatively straight and the ribs come off at almost right angles to the median sagittal plane.

RECAPITULATION:—The position of the kidneys during fetal life is wholly different from that occupied in the adult. Both axes of the kidney are different, the vertical axis, as viewed from the front, most of all.

The horizontal axes swing backward, the vertical axes, which in the fetus meet below the kidney, become parallel and then lean toward each other, meeting in the adult finally at a point above the kidneys posterior to the spine.

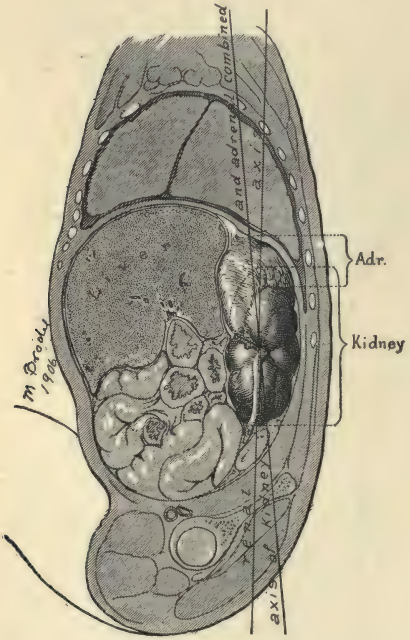


FIG. 31.—THE VERTICAL RENAL AXIS AS VIEWED FROM THE SIDE, SIX MONTHS' FETUS.

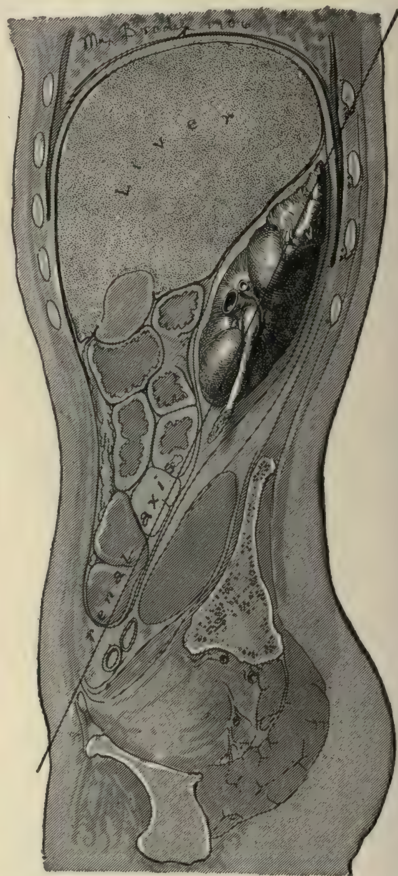


FIG. 32.—THE SAME AS FIG. 31, IN THE ADULT.

Fascia Renalis, Perirenal and Pararenal Fat.—Before describing the relation of the kidneys to the neighboring organs as seen from within, it will be well to give a description of the renal fascia, the two leaves of which sur-

round the kidney and the adrenal body. The deposition of the fat in the vicinity of the kidney will also be described.

The niches containing the kidneys are, as we have seen, broad and deep above; narrow and shallow below. They are padded with a layer of fat, the pararenal fat, which is separated from the muscles by a layer of fascia, which is thin in its upper portion—fascia transversalis, fasciæ quadratus and psoas

FIG. 33.—TRANSVERSE FROZEN SECTION OF THE BODY AT A LEVEL JUST ABOVE THE KIDNEY, SHOWING RENAL FASCIA AND FAT, AND THEIR RELATION TO SURROUNDING ORGANS.

—but increases in thickness below, where it fuses with the pelvic fascia. This layer of fat is continuous with the retroperitoneal fat of the lateral and anterior abdominal wall and above with that of the diaphragm. Medianward it communicates with the fat behind the large abdominal vessels, and below extends to the iliac fossa and farther down to the pelvis. At the diaphragm between its median and lateral muscular fibers, this pararenal fat communicates not infrequently through a narrow gap with the subpleural cellular tissues; and it is here that diaphragmatic hernias usually occur (Fig. 39).

At the region of Petit's triangle, i. e., the outer border of the quadratus lumborum, just above the crest of the ilium, the lumbar fascia is perforated by a number of vessels and nerves, each of which may have a small amount of fat accompanying it, and it is in this region that abscesses traveling through the pararenal fat are most apt to work their way out.

The amount of fat around the kidney varies, of course, greatly. It may be only a few millimeters in thickness; on the other hand, in well nourished

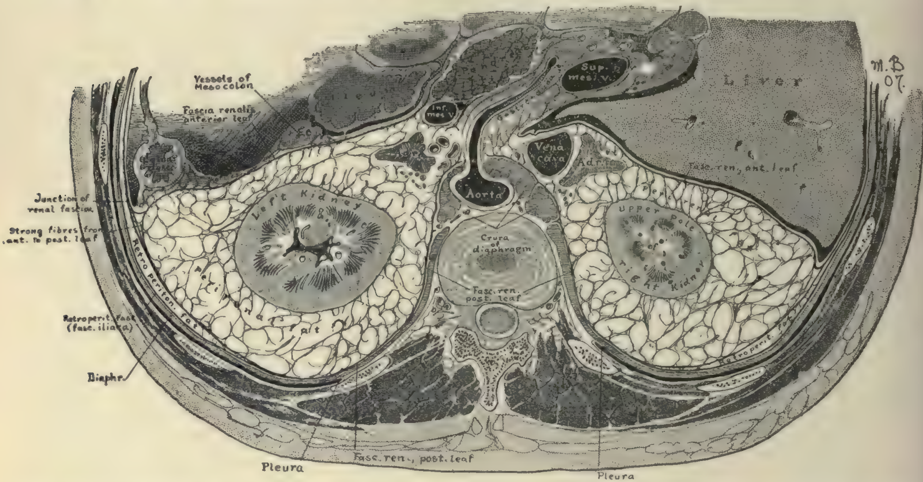


FIG. 34.—SECTION OF THE BODY 4.5 CM. LOWER THAN FIG. 33. Note the division of the renal fascia into anterior and posterior leaves, surrounding the perirenal fat while the retroperitoneal fat is behind it.

individuals it can attain enormous proportions. Present in the newborn babe, we have also repeatedly observed it in fetuses of five, six, and seven months.

Figures 33, 34, 35, 36, 37, and 38 are frozen sections through an individual with layers of fat of unusual thickness, figures especially instructive for the reason that the fasciæ and the architecture of the fibrous framework in the fat appear with much clearness owing to the tension.

The *pararenal fat* in the first section (Fig. 33) is not visible, as it terminates at a slightly lower level. In Figure 34 it appears as a narrow strip along the lateral posterior border of the renal niche. It is separated from the diaphragm by a thin fascia.

In Figure 35 the pararenal or retroperitoneal fat is considerably thicker, and also extends farther medianward, filling the corner between the sacro-

spinalis and quadratus lumborum. The fascia separating it from the muscles is continuous with the fascial sheaths enveloping the muscles.

Still farther down at Figure 36 (section through the region of the umbilicus) this layer of fat has attained its greatest thickness and it appears as a pad for the kidney to rest upon. Medianward it extends as far as the M. psoas and fills the gap between that muscle and the quadratus lumborum.

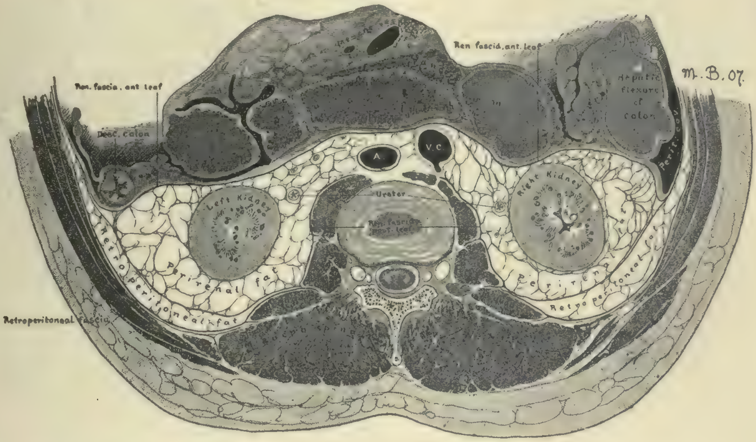


FIG. 35.—SECTION OF THE BODY 6 CM. LOWER THAN IN FIG. 34. Note changed proportion between perirenal and retroperitoneal fats.

From the muscles of the back this fat is separated by the fascia of the Mm. transversalis, quadratus, and psoas.

In sections (Figs. 37 and 38) the pararenal fat is seen to rapidly decrease in thickness. It lies in the iliac fossa and is separated from the muscles by the iliac and psoas fasciæ.

The perirenal fat (capsula adiposa), i. e., the fat in immediate contact with the kidney, communicates in no way with the pararenal fat, but is an entirely independent layer, completely surrounded by the two leaves of the fascia renalis. Comparatively thin above, it extends well up under the diaphragm, where it appears (Fig. 33) as a wedge on either side of the vertebra. It surrounds the adrenal bodies and medianward ends behind the vena cava on the right and in front of the crura of the diaphragm on the left.

The capsula adiposa increases in thickness as we get farther down and attains its maximum size at about the hilum of the kidney. Figure 34 is cut just above the hilum of the left kidney; the right, being at a somewhat lower

level, has been cut through its upper pole. Both adrenal bodies are seen some distance away from the kidneys, a considerable amount of renal fat being between the two organs. Medianward the fat extends as far as the large vessels of the abdomen. It seems as though the layer of fat posterior to the kidney were thicker than that in front, a condition appearing much clearer in thin individuals, when hardly any fat is seen in front of the kidney, while behind and at the hilum there is found a considerable amount.

Figure 35 is cut through the lower poles of both kidneys. It shows the

FIG. 36.—SECTION OF THE BODY 6 CM. LOWER THAN FIG. 35, ENTIRELY BELOW THE KIDNEY. Note narrowing of funnel of perirenal fat, in the renal fascia, and corresponding increase in amount of retroperitoneal fat.

perirenal fat more strongly developed laterally and posterior to the kidney than anteriorly. The ureter, large abdominal vessels, and lumbar glands are enveloped in this layer.

In Figure 36 (through umbilicus) the perirenal fat is cut through the funnel-shaped lower portion. The ureter, although lying close against the psoas, is surrounded by this layer. Still farther down the perirenal fat rapidly decreases in thickness, and in Figure 37 is only a narrow strip just in front of the M. psoas; it envelops the ureter and the ovarian (spermatic) vessels and extends toward the middle line of the body.

In the pelvis it follows the course of the ureter and occasionally the ovarian vessels or the external iliac, but as a rule it becomes lost at a higher level.

The perirenal fat is rich in tortuous vessels, the veins being few in number,

large in caliber. The vessels traverse the fat in all directions, following the course of the fibrous bands which divide the fat into compartments. These vessels pass either from the hilum anteriorly or posteriorly into the fat coming from the renal vessels, or emerge out of the kidney, preferable at the lateral portion of its anterior surface. Occasionally, small branches from the aorta

FIG. 37.—SECTION OF THE BODY 6.5 CM. LOWER THAN FIG. 36. Both fats are narrowed, the perirenal has almost disappeared.

direct, or from the adrenal artery, lumbar artèries, ovarian arteries, or even the common iliac, are seen passing into the perirenal fat.

The distribution of this fat is quite characteristic and deserves closer study. In adults it is found more developed than in children, where it is occasionally wanting, and women have a thicker deposit than men. Anteriorly it is very sparse and at the areas of contact with the soft and yielding intestines is generally absent.

On the other hand, at the posterior surface between the kidney and the unyielding ribs and muscular wall, there is a considerable amount, increasing in thickness at the poles, especially the lower one, and at the hilum. At the lower pole the kidney rests in its cushion of fat as in a nest (Fig. 40). This soft bed allows the kidney to execute its normal movements caused by the

diaphragmatic motion. The great deposit around the hilum is a protection to the renal pedicle, permitting at the same time the pelvis and vessels to change their volume.

The lower portion of the fat splits into two channels, a main triangular

FIG. 38.—SECTION OF THE BODY 5.5 CM. LOWER THAN FIG. 37. It is now in the pelvis. Both perirenal fat and retroperitoneal fat are still traceable and the ureter remains in the fascia.

mass lateral to the psoas and a smaller deposit following the ureter (see Fig. 40 A).

The capsula adiposa or perirenal fat is enveloped by the f a s c i a r e n a l i s, a rather delicate membrane, consisting of two leaves, a prerenal and a retrorenal layer, the latter of which is sometimes called iliac fascia. Both layers unite above, below and laterally to the kidney, but not medianward, where the posterior leaf is attached behind the large abdominal vessels to the vertebræ, while the anterior leaf passes over to the other side in order to continue as prerenal fascia of the other kidney. Above, the two leaves of renal fascia

unite near the tendinous portion of the diaphragm with which they fuse; below, they unite anywhere between the region of the iliac crest and the femoral ring, according to the amount of fat present. They remain, however, somewhat apart where the ureter passes between them. Lateral to the kidneys the two leaves unite at a varying distance, the length of which again depends upon

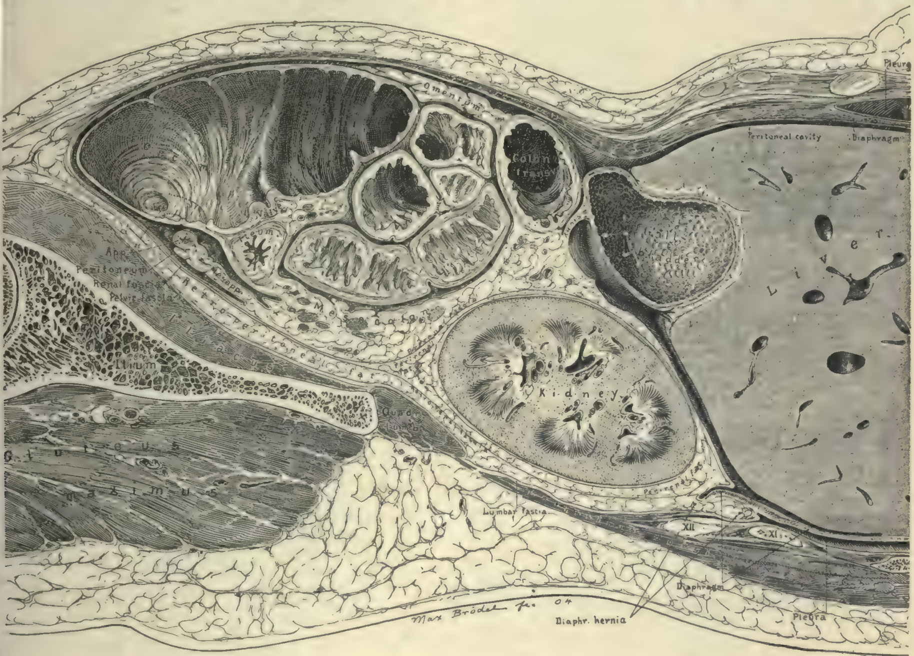


FIG. 39.—LONGITUDINAL SECTION OF THE BODY THROUGH THE RIGHT MAMMARY LINE, SHOWING THE RELATIONS OF THE PERIRENAL FAT AND THE RENAL FASCIA.

the amount of fat present. Approximately, this union takes place just behind the colon ascendens on the right and the colon descendens on the left. When united the two leaves pass forward directly under the peritoneum between it and the layer of retroperitoneal fat above described.

There is an extensive fibrous framework passing through the perirenal fat between the leaves of the fascia and the fibrous capsule of the kidney, and also around the sides and poles of the kidneys from the anterior leaf over to the posterior. The fat fills the spaces between these fibrous bands and it depends upon the amount whether the bands are long or short. The more fat there is, the more rigid is the framework enveloping the kidney. If the fat disappears or decreases in thickness in so short a space of time that the fibrous

framework has not a chance to contract, the kidney acquires a considerable degree of mobility inside its fascia. Figure 41 gives a clear idea of the architecture of the fibrous framework. The section is taken through the kidney

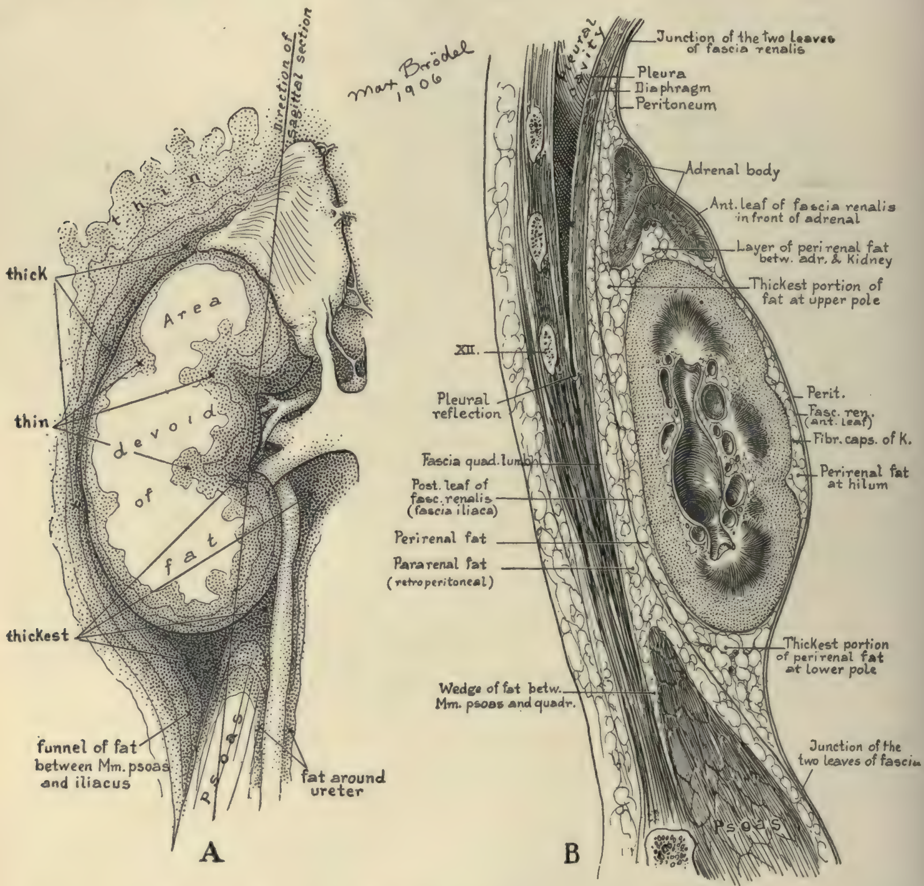


FIG. 40.—DISTRIBUTION OF THE PERIRENAL FAT IN THE AVERAGE INDIVIDUAL. A, shaded areas indicating degree of thickness of fat; all the fat is beneath the perirenal fascia and the kidney, none between this fascia and peritoneum. B, the sagittal section through line shown in left figure.

near the hilum in order to include the adrenal body. From the fibrous capsules of the kidney delicate strands are seen arising which pass in all directions through the perirenal fat, becoming attached to the inner surface of the renal fascia. At the pole of the kidney they form baskets, the upper of which is for

the adrenal, the lower for the kidney itself. At the poles the attachment of the fibers is firmer and broader than elsewhere; for which reason the fat is stripped off with greater difficulty at the poles than at the anterior and posterior surfaces.

From the outer surface of the renal fascia new fibers are seen to arise, passing to the walls of the renal niche behind and to the peritoneum and extraperitoneal surfaces of the intestines in front. Those at the posterior surface run through the pararenal or retroperitoneal fat before they become attached to the fascia transversalis and quadratus lumborum, etc. Those in front traverse no fat.

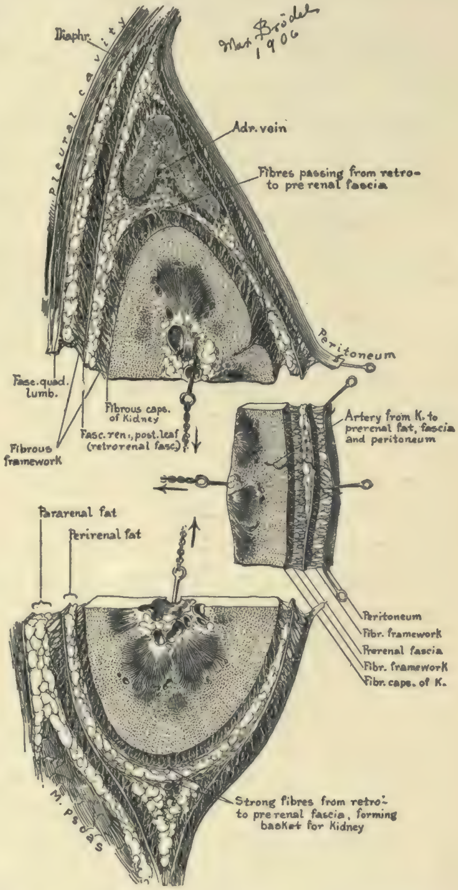


FIG. 41.—THE RENAL FASCIA AND PERIRENAL FAT. The fibrous framework is shown as though subjected to tension in order to show its architecture.

Studying the renal fascia in sections (Figs. 33-38), we find in Fig. 33 the *prerenal fascia* passes on the left under the peritoneum behind the spleen, in front of the adrenal over the crus of the diaphragm, over to the right side. It then passes behind the vena cava along the posterior surface of the liver, until it terminates near the lateral portion of the diaphragm. The *retrorenal fascia* remains in close contact with the diaphragm, passing in front over the crus, where it fuses with the prerenal leaf. Strong septa pass between the two leaves at their lateral portions so as to produce a narrow fascial pocket. In the center of the renal fat there are numerous strong fibrous trunks seen in cross section. These are the bands which pass from the upper pole of the kidney lateral to the adrenal body in an upward direction, to become attached at the apex of the fascial pocket to the tendinous portion of the diaphragm. These strands of

fibers are firmly fastened to the upper pole of the kidney and to them is due the erect position of the organ. This explains why, in freeing the kidney from its adipose capsule during an operation, considerable difficulty is always experienced in bringing the upper pole into view.

Figure 34 shows the arrangement of the two leaves of fascia and the architecture of the fibrous framework passing between the kidney and the fascial pocket. On the left the prerenal leaf is seen coming from under the peritoneum lateral to the empty descending colon, passing behind the mesocolon and its vessels and in front of the adrenal and pancreas. On the right it comes from the front of the vena cava and adrenal and passes outward just below the peritoneum to the lateral abdominal wall. Note that while the prerenal fascia on the right is separated from the peritoneal cavity only by a thin membrane, the peritoneum, on the left, it has the entire thickness of the mesocolon in addition to the peritoneum between it and the peritoneal cavity. The retrorenal leaf branches off from the prerenal leaf on the left, behind and lateral to the colon, passing parallel to the diaphragm and separating the perirenal fat from the pararenal layer. More medianward it comes into immediate contact with the diaphragm; it then passes forward over the crus and aorta. On the other side it is arranged identically, only that it passes behind the vena cava.

The architecture of the fibrous framework passing between the fibrous capsule of the kidney to the fascial pocket is worthy of note. Strands of tissue are seen running in all directions, appearing more numerous and stronger at the lateral border of the kidney. In the vicinity of the kidney, almost in close contact with its fibrous capsule, these are united with one another by short bundles passing between them, an arrangement which produces the effect of another layer of this fascia immediately enveloping the kidney.

The septa passing from the prerenal over to the retrorenal leaf, which laterally reduce the extent of the fascial pocket, are clearly demonstrated.

The course of the prerenal leaf (Fig. 35) is quite similar to that described in the higher section. On the left it passes behind the mesocolon and its vessels and farther medianward runs behind the duodenum, which it separates from the aorta and vena cava. On the right it is situated just behind the mesocolon of the hepatic flexure. Farther lateral to the colon it is immediately underneath the peritoneum.

The retrorenal leaf in its lateral half lies between the para- and perirenal layers of fat; but in its median portion it lies in close contact or it fuses more or less with the fasciæ covering the Mm. quadratus and psoas. The retroperitoneal leaf on both sides passes behind the large vascular trunks of the

abdomen, in contradistinction to the condition on the sections represented in Figures 33 and 34. The fibrous framework traversing the fat is again more in evidence at the lateral portion of the kidney, and perhaps at the region of the hilum, than elsewhere. The septa passing antero-posteriorly across the lateral corners of the renal fascial pocket are becoming more marked the farther down the section is taken.

Figure 36 is taken below the kidneys, through the lower portion of the funnel-shaped renal pocket. Beginning again from the left we find the prerenal and retrorenal leaves run together a considerable distance behind the peritoneum and mesocolon before they begin to split in order to envelop the small amount of perirenal fat which fills the lower apex of the funnel. The prerenal leaf crosses over to the other side in front of the aorta and vena cava; the retrorenal leaf runs to the psoas, where it bends forward in order to fuse with the fascia covering that muscle. It becomes lost in the fibrous tissue between the lumbar glands and the vertebræ. The ureters have reached a more median position, where they lie in close contact with the posterior fascial leaf, while the lower funnel of the renal pocket passes down in the iliac fossa, lateral to the psoas muscle. Figure 40 shows this arrangement well. The lower portion of the perirenal fat splits in two channels, between which the psoas protrudes (Fig. 36). The two leaves of renal fascia surround, therefore, three distinct groups of tissue; two layers of fat, one on either side of the vertebra and the large vessels of the abdomen with surrounding fat, lumbar glands, etc. The cross sections of the two ureters are found at the junction of these three areas.

The architecture of the fibrous framework is such that most of the strongest bundles pass in an up and down direction; i. e., from the lower pole of the kidney into the lower end of the funnel.

The last two sections, Figures 37 and 38 (taken below crest of the ilium), show the fat rapidly diminishing in thickness, bringing the two leaves of the renal fascia in close contact. The ureters are situated medianward to the psoas in Figure 37, while the lowest apex of the funnel of renal fat is lateral to the psoas. Still farther down in the region of the pelvis the ureters are posterior to the iliac vessels, and the two leaves of renal fascia have fused in front of the ilio-psoas.

C. RELATION OF KIDNEYS TO THE NEIGHBORING ORGANS VIEWED FROM WITHIN THE ABDOMINAL CAVITY.

On opening the abdominal cavity with a view to inspecting the kidneys, they are found to be partially covered by other organs. In front of the right kidney lie,—

I. The descending portion of the duodenum,
II. The hepatic flexure of the colon,
III. The right lobe of the liver.

In front of the left kidney lie,—

I. Stomach,
II. Spleen,
III. Pancreas,
IV. The splenic flexure of the colon,
V. Beginning of the colon descendens,
VI. A few loops of small intestines.

Both kidneys carry on the upper pole their adrenal bodies, which project over the anterior surface and median border (Fig. 50). To expose the right kidney it is necessary to lift up the liver, push the gastro-hepatic omentum and duodenum medianward and pull down the hepatic flexure of the colon. The right kidney is then seen in its upper two-thirds covered by peritoneum (see Fig. 43).

The left kidney is brought into view by pushing medianward the loops of small intestines found beneath the splenic flexure of the colon, and by drawing the transverse colon, stomach and pancreas upward. The left kidney is then seen between the flexura duodeno-jejunalis and the colon descendens, being discernible in its lower two-thirds, although covered by the mesocolon and its vessels (Fig. 47).

It is impossible to draw the colon medianward without tearing the peritoneal reflection along the lateral margin of the colon. The exposure of the left kidney is therefore incomplete.

The position of the abdominal organs in relation to the kidneys is subject to considerable change even in the same individual, the main factors being a greater or lesser degree of distention of the stomach and intestines with food or gas and the changing position of the body, whether erect, lying on the back, on the side, on the abdomen, or placed in knee-elbow posture. The following remarks apply to the body lying on its back:

The Right Kidney.—Duodenum.—The extraperitoneal part of the posterior surface of the descending portion of the duodenum is closely attached to the median surface of the kidney, to which it is fastened by a strong peritoneal

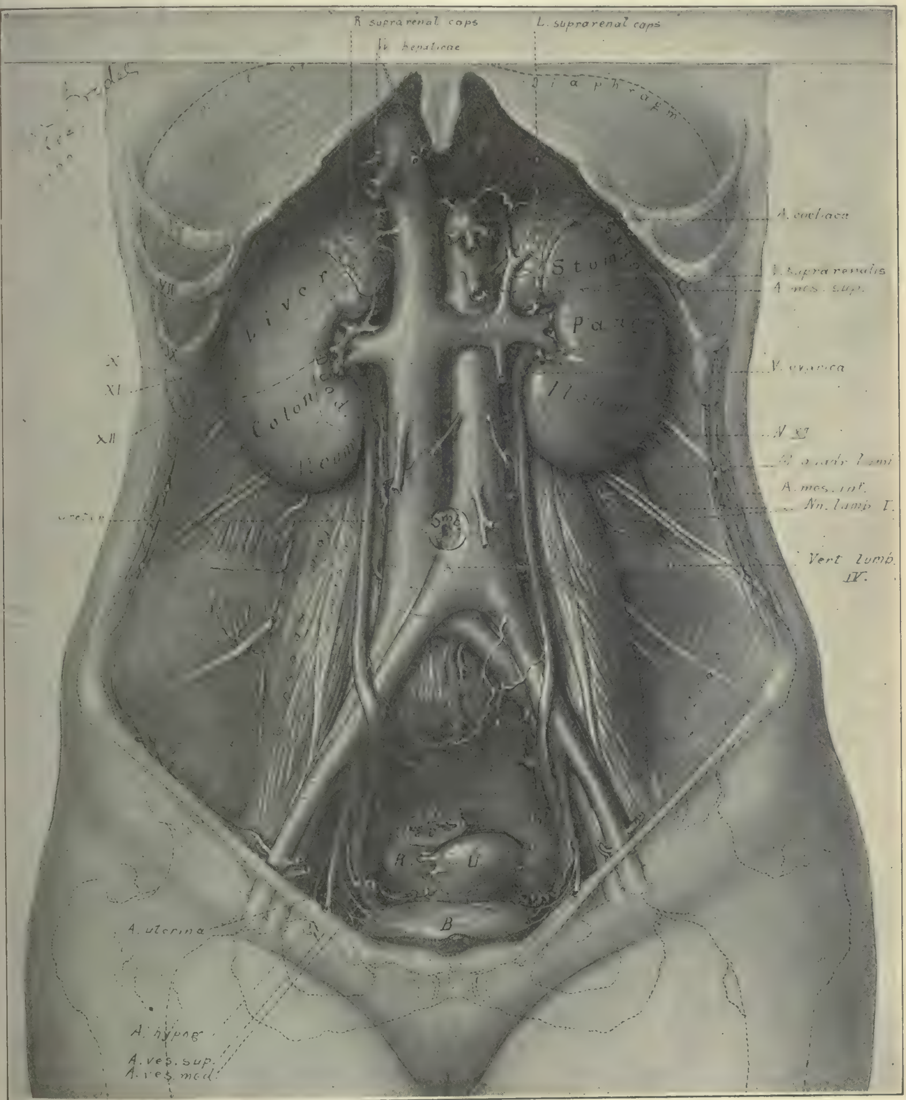


Fig. 42.—The Position of Kidneys, Ureters and Bladder. Front view: abdominal viscera removed.

fold, the duodeno-renal ligament (Fig. 43). The extent of the area of contact varies; it is inversely proportional to that of the colon. With a distended

FIG. 43.—DISSECTION SHOWING RIGHT KIDNEY *IN SITU;* EXPOSURE OBTAINED BY RETRACTING LIVER AND HEPATIC FLEXURE OF COLON. Note peritoneal folds, sometimes characterized as nephro-hepatic and nephro-colic ligaments.

colon the duodenum is pressed medianward; a distended duodenum, on the other hand, pushes the colon away from the kidney in an anterior direction. As a rule the area of contact is larger in women than in men, on account,

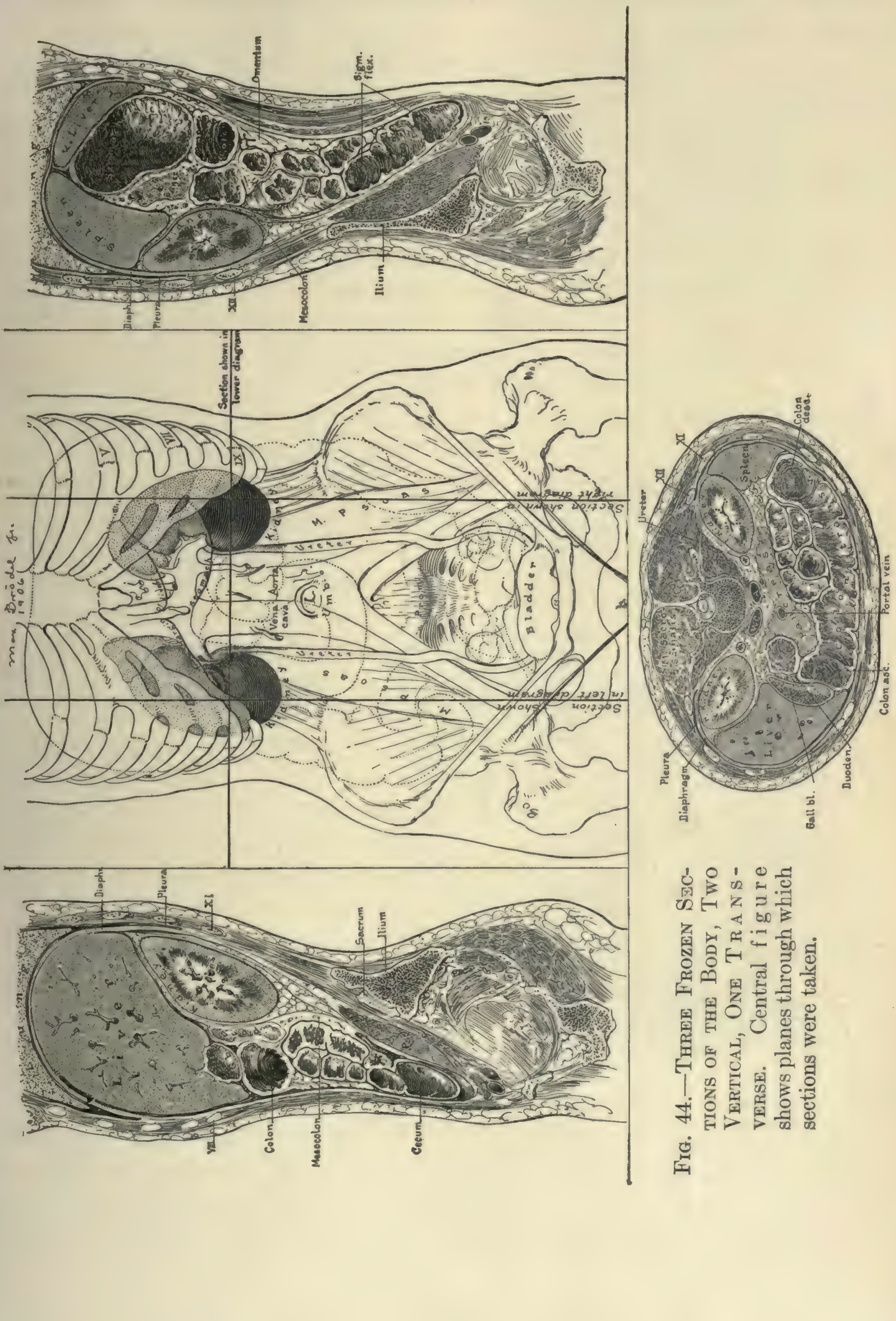


FIG. 44.—THREE FROZEN SECTIONS OF THE BODY, TWO VERTICAL, ONE TRANSVERSE. Central figure shows planes through which sections were taken.

perhaps, of the more cramped position of the organs in the narrow upper abdominal region.

A floating kidney, especially if descending together with its fascia-capsule, has a tendency to drag down the duodenum, sometimes for a considerable distance. This is due to the intimate connection between the two organs, also demonstrated in cases of general enteroptosis, where the descending stomach and duodenum carry along the right kidney. The forces acting upon the kidneys in such cases are of such complex nature that an analysis would lead too far from our present subject. The orifice of the ductus choledochus is about opposite the hilum, that of the accessory pancreatic duct, 2 cm. above (see Fig. 45).

Colon.—The retroperitoneal portion of the hepatic flexure of the colon comes in contact with the lower pole of the kidney, the area varying, however, with the degree of distention of the duodenum. Its attachment to the kidney is loose and it is with ease drawn away (Fig. 43). The peritoneum of the posterior surface of the colon is reflected over the lower pole of the kidney. The angle between the ascending and transverse portions of the colon is obtuse, and often a forward curve is noticeable (Fig. 43), which breaks the angle up into two; namely, a flexura renalis, situated at the lower pole of the kidney, and a flexura hepatica, which is more anterior and higher up. Frequent variations are, of course, numerous, and result from the varying positions of the kidney, liver, duodenum, and, finally, from abnormal position of the colon itself. The cecum may be so high as actually to lie in front of the lower pole of the kidney, and the appendix runs behind the colon much more frequently than is generally supposed, in an upward direction, with its tip in the vicinity of, or adherent to, the peritoneal covering of the right kidney.

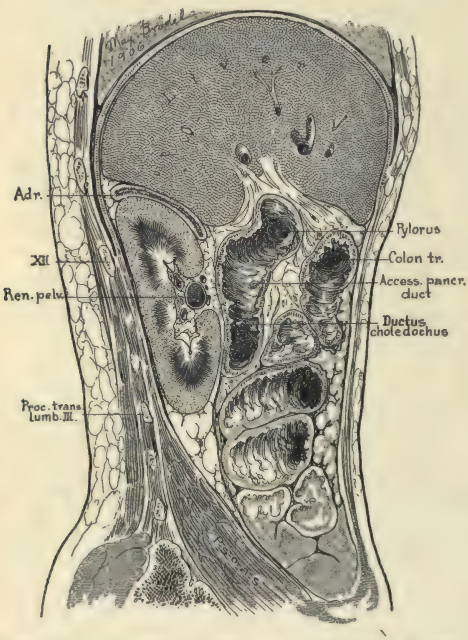


Fig. 45.—Sagittal Section Through Right Mammary Line, Showing Relation Between Right Kidney and the Bile and Pancreatic Ducts.

Compared with the splenic flexure the relation of the kidney to the hepatic flexure is subject to much less variation; this because the liver covers so much of the kidney that the colon has less freedom for variation.

Owing to the close proximity of the duodenum and colon, perinephritic abscesses are apt to open into them, most liable to occur if the perinephritic fat is scanty or absent and if the kidney be adherent to the intestines; otherwise the abscess usually drains in the direction of least resistance; i. e., between the leaves of the renal fascia in an upward or downward direction.

Liver.—The upper outer two-thirds of the right kidney are in contact with the liver, which, as the more plastic organ, receives an impression in its lower surface appearing as a more or less accurate mold of the upper portion of the kidney. Such depressions are much less marked on the living subject than on cadavers, where they appear with sharply defined outlines.

On lifting the liver up, away from the kidney, a few delicate peritoneal folds are demonstrated. These are strengthened by strands of renal fascia and have been termed the hepato-renal ligament (Fig. 43).

The size of the area of contact varies considerably:

(1) In cases of a long, turned-down lace-liver, without descent of the kidney, the whole of the kidney may be covered by the lower surface of the liver, pointing in such cases posteriorly. The liver may then assume the shape of an hour glass (Fig. 46).

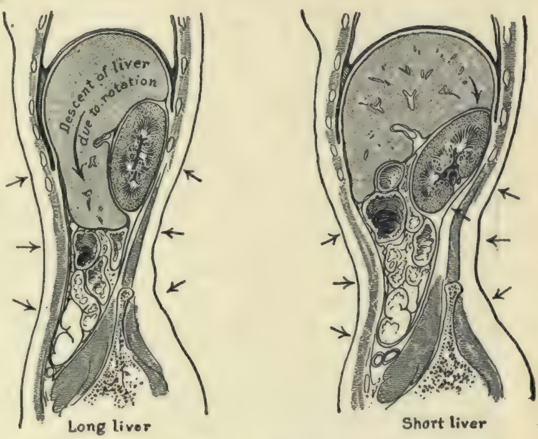


Fig. 46.—Forms of Liver Due to Lacing. (After Hertz.)

(2) In short, high lace-liver, which is entirely above the level of compression, the area of renal contact may be small, the liver touching only the upper pole of the kidney. The lower pole is then usually pressed anteriorly, bringing the length axis of the kidney into an angle of 45 degrees or more with the long axis of the body (Fig. 46).

Between these two extremes there are many transition forms.

The Left Kidney.—Stomach.—The upper outer portion of the anterior surface of the left kidney is in contact with the stomach; the size of the area

varying from 1 to 3 cm. in width. It increases in a state of distention of the stomach, and may be *nil* in a state of contraction (Figs. 24 and 49). The two organs are separated by the peritoneum of the lesser peritoneal cavity.

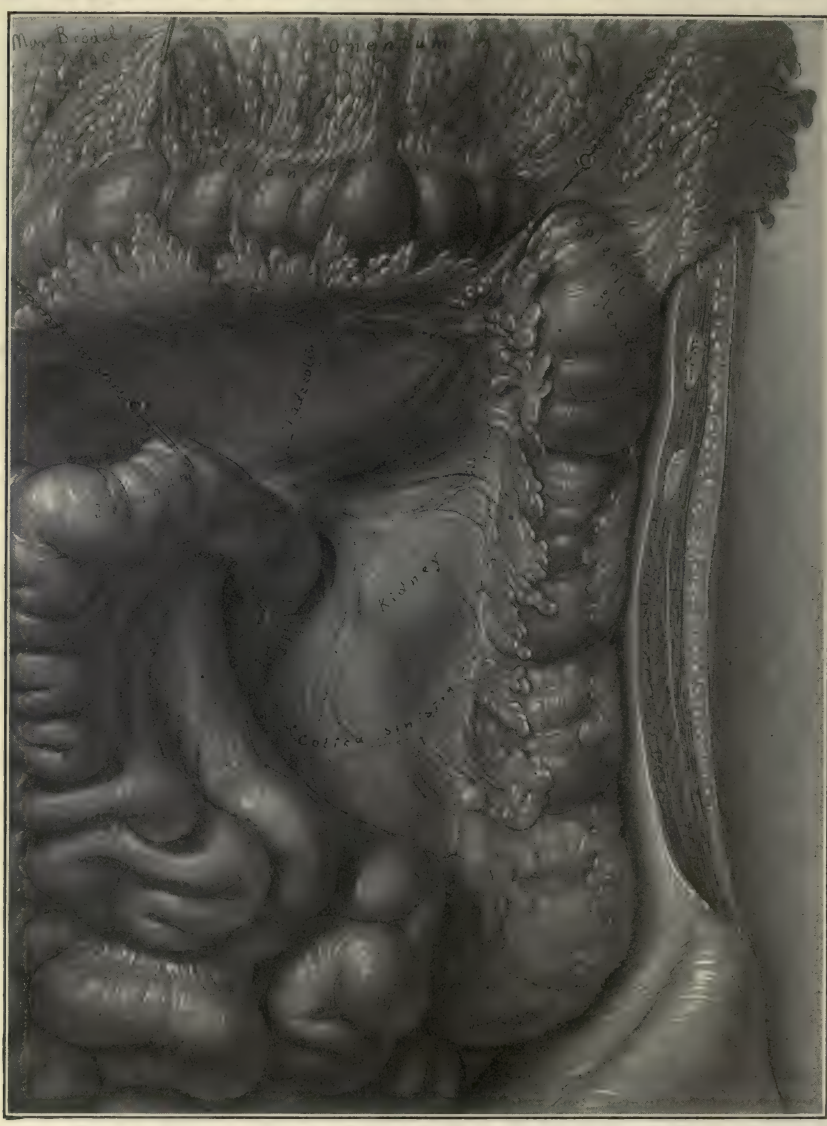


Fig. 47.—Section Showing the Left Kidney *In Situ* From the Front. Through the retraction of the colon and omentum upward, and the small intestines to the right, the lower pole of kidney is exposed. It is, however, covered by mesocolon.

Spleen.—The area of contact with the spleen likewise varies. It is, as a rule, situated along the upper outer border of the kidney and may extend downward for one-quarter to one-half the length of the organ (Fig. 24). Its size depends upon the degree of distention of the stomach and intestines, so that an empty stomach permits the spleen to drop down and cover an area

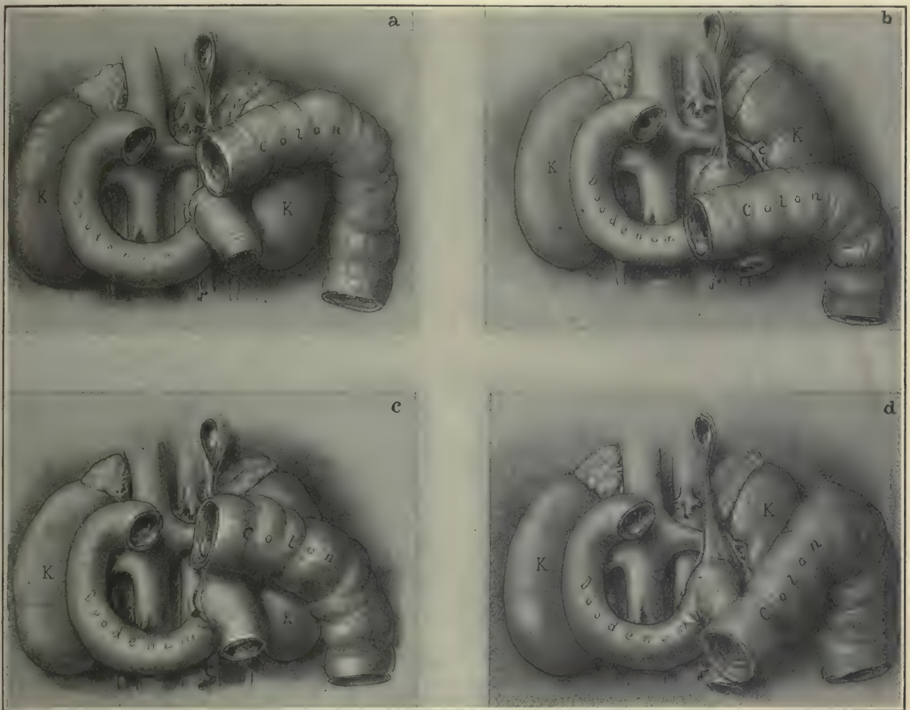


Fig. 48.—Diagrams Representing the Four Most Frequent Positions of the Splenic Flexure of the Colon.

which had been occupied by the stomach (Fig. 49). Both organs have intervening peritoneum.

Pancreas.—The center of the left kidney is crossed transversely by the pancreas and the splenic vessels (Figs. 24 and 49). The width of the area is constant, measuring 3 cm., but it may be situated at various levels. As a rule, it crosses somewhat above the hilum. The pancreas is in intimate contact with the anterior leaf of the renal fascia, with no peritoneum separating the two surfaces. Occasionally the attachment is not so intimate, when we find the

peritoneal covering of the anterior portion extending around the lower border, to ascend for a short distance until it becomes reflected over the kidney. Along the upper border of the pancreas there are the splenic vessels, the artery being above the vein.

Owing to the more intimate connection between the pancreas and the kid-

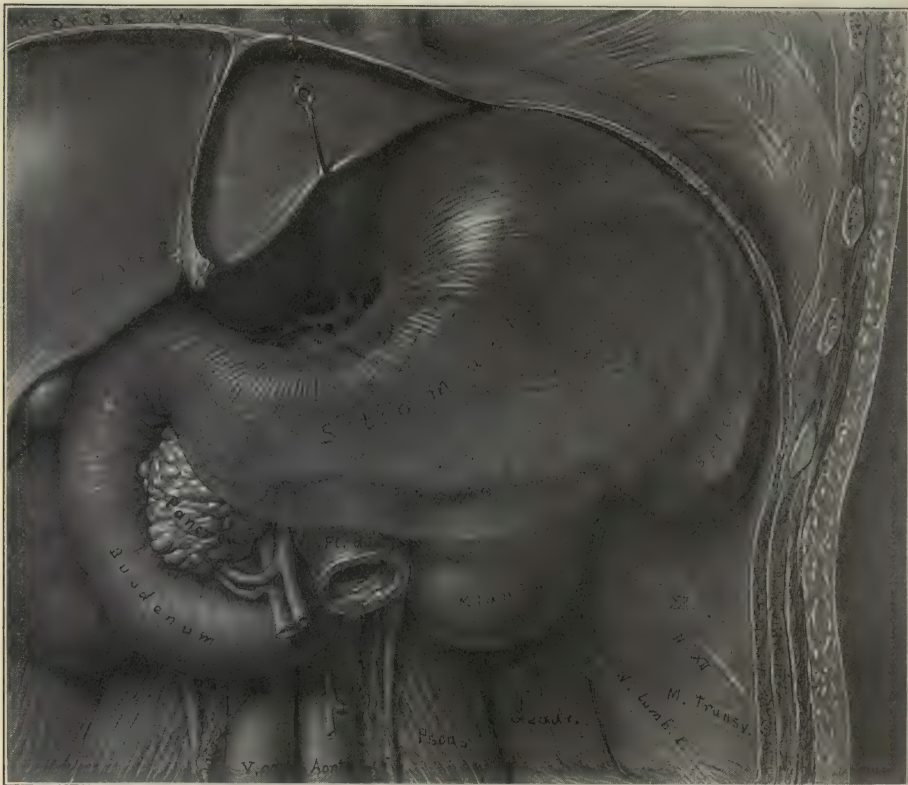


Fig. 49.—Dissection Showing From the Front the Relations of the Kidneys to the Stomach, the Pancreas, the Duodenum and Spleen. For the sake of clearness the stomach is represented as though transparent.

ney, it not infrequently happens that in cases of movable or floating kidney the pancreas follows the kidney.

Splenic Flexure of the Colon.—Owing to the greater freedom of the colon on the left side, the relation between the splenic flexure and the left kidney is subject to more variation on that side.

The angle between the transverse and descending colon is generally acute, caused by the oblique direction of the transverse portion (Fig. 48d). The kidney is crossed by the end portion of the transverse colon; the level varying anywhere between the upper and lower poles. As a rule, it crosses nearer to the upper pole, as shown in Figure 47 and Figure 48a. This level corresponds to that of the XII rib. A lower arrangement such as shown in Figure 48b is quite frequent and indicates the presence of a distended or descended stomach.

Rarely is the end portion of the transverse colon seen drooping as in Figure 48c. Finally, the fourth form (Fig. 48d) is usually associated with general enteroptosis.

Descending Colon.—The descending portion passes invariably along the outer border of the kidney, especially if the bowel be empty; in a state of distention, however, it swings medianward in a direction toward the kidney, covering more of the anterior surface of the latter.

On lifting the transverse colon upward and the loops of the small intestine to the right side (Fig. 47), one can readily expose the lower portion of the left kidney, covered by the mesocolon, in which are passing the colic vessels.

The main trunk of the colica sinistra curves outward just beneath the lower pole of the kidney and anastomosing branches to the colica media are seen passing over the anterior surface of the kidney on their way up to the splenic flexure and to the transverse colon.

Small Intestine.—A few coils of small intestine are in contact with the lower pole of the left kidney, the thin mesocolon with its vessels intervening. They belong to the jejunum, and their area of contact is inversely proportional to that of the splenic flexure and descending colon.

The duodenum at its junction with the jejunum is often in contact with the hilum or median portion of the lower pole (see Fig. 47).

The Adrenal Bodies.—The two adrenal bodies are situated at the median upper portion of the kidneys, between their poles and the large vascular trunks of the abdomen (Fig. 50). They are flat organs, which with their concave base rest upon the kidney like a cap, while their anterior portion extends down toward the hilum of the kidney. The hilum of the adrenal bodies is situated on their median anterior surface, where the vessels are seen to enter and leave the organ. The right adrenal body has a flattened triangular form and is situated somewhat nearer the top of the kidney than the left. It resembles a pyramid, the apex of which projects upward between the liver and the vena cava. The liver receives a distinct impression from the right adrenal, which is, of course, more marked in the cadaver than in the living subject. The right adrenal body is in close contact with the vena cava and its median border

may even extend a short distance between the vena cava and the vertebral column. The adrenal vein is therefore quite short on that side. There is often a second vein draining into the right renal vein. Frequently this is the main adrenal vein, while the upper, draining into the vena cava, is only an accessory branch (Fig. 50). The anterior surface of the right adrenal body is covered by peritoneum, with the exception of a small area near the lower end, which is covered by the extraperitoneal surface of the duodenum.

The left adrenal body is crescent-shaped, longer and more slender, and consequently extends farther down toward the hilum than the right adrenal and appears to be slightly larger than the right. It lies between the stomach and upper pole of the kidney and touches the spleen with its outer extremity. The median border of the left adrenal is somewhat raised and appears as a ridge lateral to the aorta. Posteriorly there is another vertical ridge, projecting into the triangular space between the crus of the diaphragm and the kidney. The lower portion of the left adrenal body is covered by the pancreas and the splenic vessels. The vein drains into the renal vein on that side.

The a r t e r i e s of both adrenal bodies approach the organ from three different directions, and before entering break up into smaller branches spreading out on the surface. The superior adrenal artery is a branch of the inferior phrenic artery.

The middle adrenal artery comes from the aorta directly at a level with the celiac axis and passes in front of the crura of the diaphragm to the middle of the adrenal body.

The inferior adrenal artery rises from the renal artery, close to its aortic origin on the left, while that on the right side, owing to the greater length of the renal artery, rises at a point about midway between the aorta and kidney. If the renal artery divides into several branches or if there be several separate renal arteries, the inferior adrenal branch usually comes from the uppermost of the renal branches; although it has been seen to rise from the second.

The l y m p h a t i c s of the adrenal collect at the hilum, where they form a complex network around the central vein. They communicate with the lymph vessels coming from the kidneys and empty into the receptaculum chyli.

The n e r v e s of the adrenal bodies come from the solar plexus of the sympathetic system and also from the renal plexuses. They enter the organ together with the vessels and are more numerous on the inner and lower surface.

There may be accessory adrenal bodies, which vary from 1 to 5 mm. in diameter. These are found lying either in the connective tissue covering the

surface of the adrenal body itself, or embedded in the substance of the kidney and other parts of the abdomen, especially the generative organs.

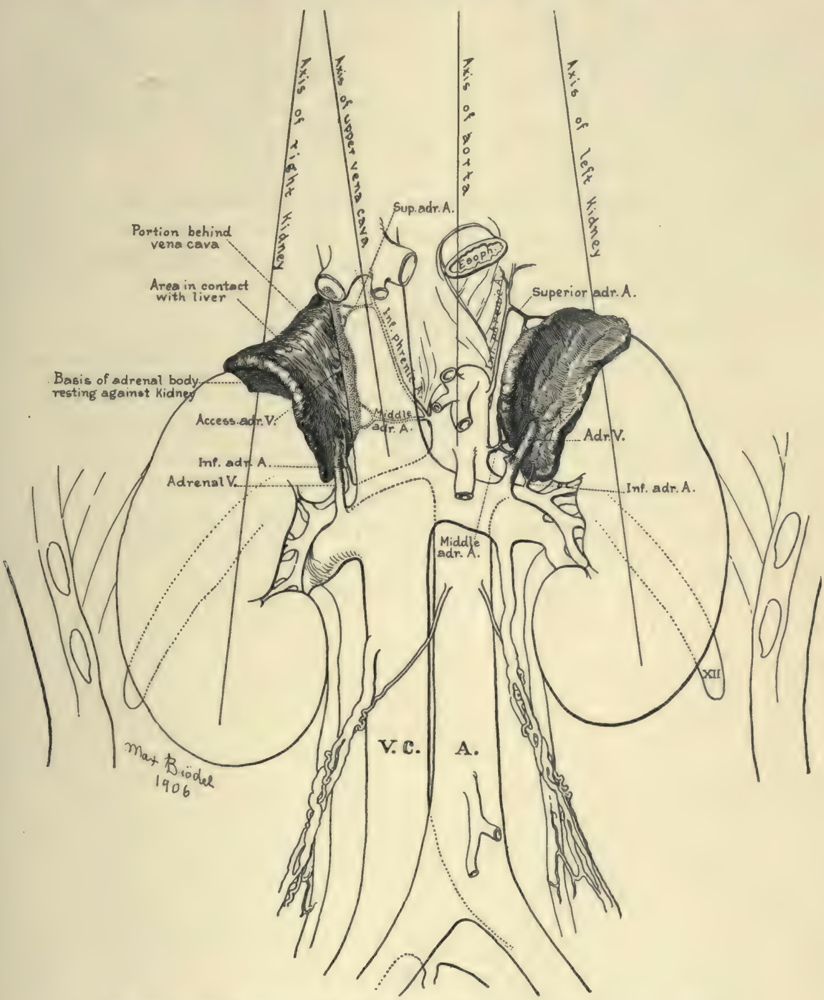


FIG. 50.—THE POSITION, FORM AND VASCULARIZATION OF THE ADRENAL GLANDS, AS SEEN FROM THE FRONT.

The topographical position of the adrenal bodies is quite constant. Nearly always found in the same place, if the neighboring organs change their relative positions the adrenals rarely follow, owing to their intimate connection with

the large vascular trunks and also on account of their numerous nerves and lymphatics. Their fixation to the two leaves of the renal fascia is equally firm; in addition, there is a strong septum passing from the anterior over to the posterior leaf between the adrenal and kidney.

Thus in cases of floating kidneys the adrenal bodies rarely descend, but remain firmly anchored in their proper place. The connective tissue fibers passing from the lower adrenal surface to the upper pole of the kidney, however, appear much lengthened.

Relation of Kidneys to the Large Vessels of the Abdomen.—The distance between the kidneys and the large vessels is not equal on both sides, but is less on the right, owing to the outward and forward course of the upper portion of the vena cava (Fig. 50).

The axes of the right kidney and upper vena cava lean much more toward one another than those of the left kidney and aorta, since the latter remains more in the median line of the body and closer to the vertebral column. The close vicinity of the vena cava to the hilum of the kidney is the cause of the relative shortness of the right renal vein; a condition which may render the removal of an enlarged kidney on that side very difficult. Owing to the forward direction of the vena cava the median portion of the right adrenal body appears partly concealed.

CHAPTER III.

EMBRYOLOGY OF THE UROGENITAL APPARATUS.

The development of the kidneys being so closely associated with that of the generative organs, a description of one necessitates an account, however short, of the other, so after briefly outlining the principal steps in the formation of the urogenital apparatus we follow with a careful account of the evolution of the permanent kidney.

The excretory apparatus in the vertebrates exists in three types: The pronephros (head-kidney or fore-kidney), the mesonephros (Wolffian body or mid-kidney), and the metanephros (permanent kidney or hind-kidney). All three possess a duct, a system of straight or convoluted conducting channels and glomeruli. While the tubules of the pronephros atrophy, the duct is preserved and changes into the Wolffian duct, from the lower end of which finally originates the duct of the permanent kidney, the ureter, through the process of budding.

The pronephros is permanent only in myxinoides (low order of fishes) and becomes rudimentary in a somewhat higher order of vertebrates (fishes and amphibia), in whom its place is taken by the mesonephros or Wolffian body, which serves as urinary apparatus, its upper portion changing into the male generative organ. In the adult amniota the Wolffian body performs no secretory functions, but is found rudimentary in the generative organs.

In man the development begins apparently with the formation of the Wolffian duct, named after Caspar Friedrich Wolff. This is the excretory channel of the mesonephros, mid-kidney or Wolffian body, whose formation is secondary to that of the duct. However, in very young human embryos (3 to 5 mm. in length) a delicate tube has been observed cranialward to the Wolffian body, with or without a tubule and funnel-shaped opening into the celom, which may be considered a rudiment of the duct of the pronephros or head kidney.

After the Wolffian body has fairly well advanced in its development, one observes the formation of another duct—the Müllerian—named after

Johannes Müller. In embryos of 17.5 mm. length this channel is first distinguishable with a low power lens, when it is seen running along the outer border of the Wolffian body, parallel and lateral to the Wolffian duct. Its upper end, situated somewhat above the level of the top of the Wolffian body, consists of one or several funnel-shaped openings, by means of which the duct stands in free communication with the celomic cavity. Lower down, at about the level of the lower end of the Wolffian body, the Müllerian duct crosses over in front of the Wolffian duct to join its fellow of the other side. Both then run close together to the urogenital sinus, which is reached in embryos of about 3 cm. in length. The lower ends of the Müllerian ducts are then found as a thick ridge projecting along the dorsal wall of the sinus, between and somewhat below the orifices of the Wolffian ducts in the cloaca, but, unlike the latter, not opening into the sinus for some time, communication taking place about the end of the second month of intrauterine life. The Müllerian ducts give rise to the uterine tubes, uterus and vagina in the female; while in the male the middle portion disappears, the anterior persisting in the hydatids of Morgagni and the posterior becoming the uterus masculinus, or Weber's organ. Together with the growth of the Müllerian duct we observe the formation of the sexual gland. While the former develops along the lateral border of the Wolffian body, the latter takes its origin from a thickening of the celomic epithelium on the mesioventral surface of the Wolffian body. This thickening occurs in the form of a ridge stretched in an up and down direction in the middle portion of the Wolffian body. The differentiation of sex does not appear until some time later when the germinal epithelium becomes much thickened, at the same time growing into the depth in the form of epithelial columns. Mesoblastic cells enter these columns and break them up into groups of germinal epithelial cells, each group containing one or several primordial ova. Thus we have to deal with the early stage of an ovary, while the manner of formation of a testicle differs from this in so far as the germinal epithelium increases less in thickness. The wandering in of epithelial cells into the underlying mesoblast is, however, the same, likewise the separation of these columns by means of strands of mesoblastic tissue. Cell nests thus formed give rise to the seminiferous tubules, which become connected with the upper Malpighian bodies and through them with the tubular system of the Wolffian body.

The cranial tubules only are utilized in this manner. After they have increased in complex arrangement and in size they constitute in the adult the head of the epididymis, in the male, and the epoophoron or parovarium in the female. The tubules of the posterior or lower half of the Wolffian body de-

generate and are recognized in the adult as the paradidymis or organ of Giraldès of the male and the paroophoron of the female.

The Wolffian duct remains in the adult male as the tail of the epididymis and vas deferens, while in the female it becomes more or less rudimentary and is known as Gartner's duct.

DEVELOPMENT OF THE WOLFFIAN BODY.

The earliest indication of the formation of the urinary organs in mammals is found in the intermediate cell-mass of the mesoderm. Each protovertebra (see Fig. 51a) has a lateral extension in the intermediate cell-mass, called the

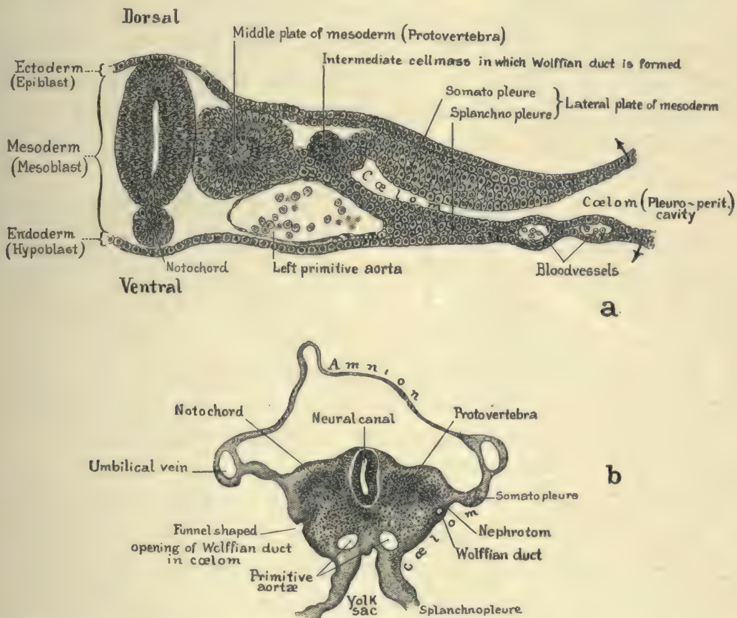


FIG. 51.—TRANSVERSE SECTION THROUGH YOUNG EMBRYOS. *b*, human being, to show origin of Wolffian ducts and bodies. (After J. B. MacCallum.)

nephrotom. These fuse with one another and thus form a ridge on either side of the mid-line and extending from the region of the arm bud down to the leg.

The formation of this ridge goes hand in hand with the development of the Wolffian duct, which appears in intimate contact with the celomic epithelium (Fig. 51b). It seems, however, that this stage is preceded by the formation

of a pronephros, although the observation of these early stages in human material has hitherto been rather fragmentary.[1] Examinations of very young embryos, from 2.4 to 4.5 mm. in length, show cephalad to the Wolffian duct, the rudiments of another duct, tubules, and even glomeruli. MacCallum (*Amer. J. Anat.,* 1901-1902, i, 245) and Gage (*Amer. J. Anat.,* 1905, iv, 409) have pointed out that in the cephalic portion of the Wolffian ridge, generally opposite the 6-8th myotome, sometimes as high as the 5th or as low as the 11th, there is a short blind tube which opens above in the form of a funnel into the celomic cavity. This blind channel has tubular branches similar to those of the Wolffian body, though curving in an opposite direction. They may or may not communicate with the celom.

On account of its position and similarity in construction with the pronephros of lower animals it is very probable that this remnant in human embryos is the upper portion of the pronephros and that the lower portion of the pronephric duct develops into the Wolffian duct. Remnants of the pronephros have been observed in human embryos ranging from 3 to 20 mm. in length.

The Wolffian duct, therefore, exists before there is any indication of the tubular system of the Wolffian body, which develops subsequently and independently from the nephrotomes or nephrogenic tissue (Fig. 51b). In intervals corresponding to the nephrotomes the Wolffian duct shows thickenings and definite enlargements. In an embryo of 3.5 mm. the Wolffian duct extended from the 10th to the 19th or last myotome of the embryo, and in its course there were thirteen thickenings. The cell-masses of the nephrotomes develop cavities or channels, which at first communicate with the celomic epithelium, but soon become closed as their connection with the above mentioned enlargements of the Wolffian duct becomes established.

This marks the origin of the tubular system of the Wolffian body. Each tubule grows in the shape of the letter S, develops a Bowman's capsule, and receives its glomerulus. This process begins at the cranial portion of the Wolffian body and proceeds toward the caudal, so the upper tubules and glomeruli are fully developed before the lower have passed the first stage. Later the tubules and glomeruli increase in number through a process of sprouting from those already existing. These sprouts are at first solid strings of cells, later developing a lumen.

In a human embryo of 4.3 mm. length Gage found practically all transition forms of tubular formations in different levels of the same Wolffian body. The number of tubules and tubular anlagen was 19.

[1] See W. Felix, "Die Entwickelung des Urogenitalsystems," "Handbuch der Entwickelungsgeschichte des Menschen," Keibel u. Mall, 1911, ii, 732.

The caudal portion of the Wolffian duct had no tubules, but merely a series of distinct enlargements of its lumen. Higher up there were groups of cells (nephrotomes) without lumen and without connection with either celomic epithelium or Wolffian duct. Cavities or vesicles deep in the Wolffian ridge were lined by epithelium of several layers, having no connection with celom or

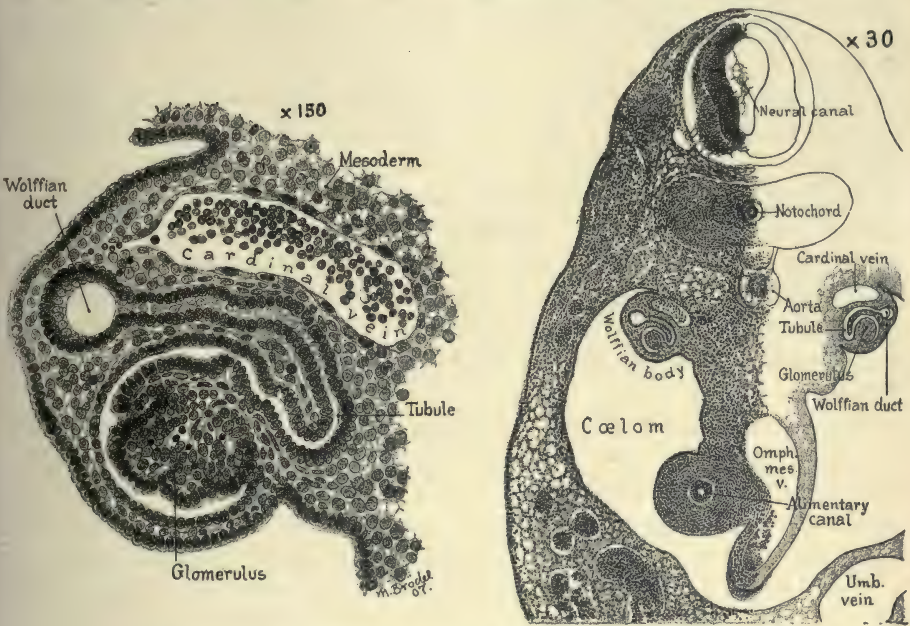


FIG. 52.—TRANSVERSE SECTION THROUGH HUMAN EMBRYO 7 MM. IN LENGTH, SHOWING WOLFFIAN BODIES.

duct. Similar vesicles connected with celomic epithelium by either a solid string of cells or a narrow channel or a wide open funnel. In the cephalic portion there was a tubule with a small opening from Bowman's capsule to the celom. Most of the tubules of the cephalic group have the typical Bowman's capsule, the S-shape, and are connected with the Wolffian duct, but not with the celomic epithelium. One of the upper tubules has two Bowman's capsules, one dorsal of the other.

In a slightly older embryo (about 23 days) all tubules and glomeruli are well formed and typical. The number of tubules has increased to 16; in another embryo of the same age to 19. They describe a double curve resembling the letter S and are regularly arrânged. Each has a small group of capillaries growing into the concave portion of its distal end, thus forming the future

glomeruli of the Wolffian body. The duct has by this time reached the cloaca, the orifice being situated at the lateral inferior region of the pouch (Figs. 55 and 60).

At the age of four weeks the small anterior duct has disappeared, although, as Tandler has pointed out, it may persist much longer (*Centrlbl. f. Physiol.*, 1905, xviii, 582). The Wolffian duct has now a system of 30 tubules, whose distal end encircles a well-formed glomerulus. At this part the tubule is slightly dilated.

Figure 52 shows a cross section through the middle portion of the Wolffian body. The duct is situated on the lateral margin of the Wolffian body and one of the 30 tubules is seen to empty into it.

In an embryo of 5½ weeks the number of tubules and glomeruli is approximately the same (27). The character of the tubules, however, has changed somewhat, as there is a well-marked differentiation into a secreting and conducting portion; the former being dilated in form of an ampulla around the glomerulus, while the latter has a narrow lumen throughout. The tubules have become markedly convoluted, similar to the convoluted tubules in the adult kidney.

The glomeruli of the Wolffian body are very similar to those found in the subsequent kidney. They are somewhat smaller in the first stages of development, measuring in the Wolffian body of a four weeks' embryo between 0.075 and 0.087 mm. in diameter. With the growth of the Wolffian body not only the number of glomeruli, but also their size, increases to a certain degree, and in the Wolffian body of a human embryo of nine weeks measure between 0.10 and 0.12 mm. The rule is that those glomeruli are largest nearest the aorta; i. e., receive their blood supply first.

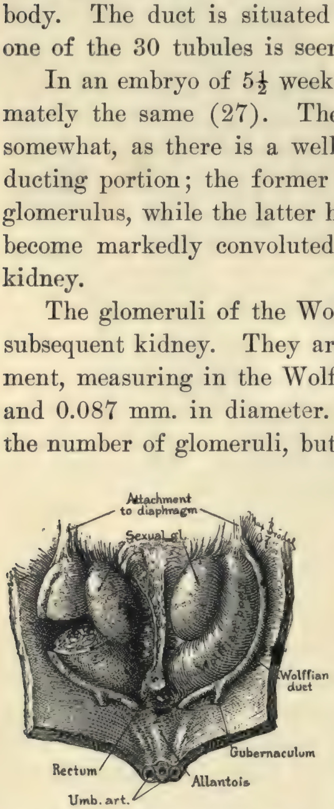


Fig. 53.—The Wolffian Body in Human Embryo, 17 mm. in Length.

The Wolffian bodies at the height of their development, which occurs at the age of about 4-5 weeks, represent two long, slightly curved organs situated on either side of the vertebral column. They border mesially on the aorta, mesentery and the two cardinal veins, anteriorly on the celom (peritoneum), and posteriorly on the body wall. Their lateral border is convex and running along it and following its curve are seen the Wolffian ducts (see Fig. 53). The lower end of the Wolffian body is somewhat tapering and projects into the pelvis on either side of the rectum. A little perpendicular band is seen to pass over the duct

and from thence down to the region of the internal inguinal ring. This is the gubernaculum, the shortening of which is associated with the descent of the testicle. In the female it persists as the round ligament. The upper end of the Wolffian body is found at a level with the heart. In front there is a long peritoneal fold passing in an up and downward direction, the germinal fold, in the middle portion of which the sexual gland develops.

The interior of the Wolffian body can be divided into two zones, mesio-ventral, containing a row of about 27 glomeruli with the ampullar dilatations of the tubules, and dorso-lateral, containing the duct with the usual number of tubules (25-30), entering either singly or in pairs at right angles and in fairly regular intervals into the duct. The arteries of the Wolffian body come from the aorta. They are 8-12 in number on each side and pass obliquely downward to the concave region of the Wolffian body, where they divide and subdivide until as many branches exist as glomeruli. The efferent vessels break up into capillaries, which surround the tubules. The collecting veins drain into the cardinal veins of the corresponding side.

The Wolffian duct in an embryo of 4.2 mm. length, also in one of 6.5 mm., empties into the lower end of the intestinal tube, which thus becomes a cloaca (Figs. 55 and 56); but in embryos of 11.5 mm. its orifice is found to have shifted in a cranio-ventral direction caused by a downward growth of the uro-rectal septum. It is now attached to the boundary between the lower portion of the bladder and the urogenital sinus; i. e., the portion of the channel which subsequently becomes the neck of the bladder (Fig. 57).

The retrogressive changes in the Wolffian body take place between the ages of 8 and 16 weeks. They consist in a diminution of the size of the glomeruli, gradual disappearance of the vascularization and consequent degeneration of the epithelial elements. The degeneration and obliteration of the tubules and glomeruli progress from the caudal extremity upward and in an 11 weeks' embryo there were only 20 tubules, in a slightly older one only 9 tubules and 12 glomeruli left. Into the upper 8 or 9 Malpighian bodies there is, as MacCallum has pointed out (*Amer. J. Anat.,* 1901-1902, i, 245), a growth of testis tubules. Bowman's capsule is perforated by the tubules coming in bundles from the hilum of the testicle and a connection is thus established between testis and epididymis.

In female embryos the upper tubules persist and converge toward the hilum of the ovary.

The ovary or testicle grows rapidly and soon exceeds the remaining portion of the Wolffian body in size, until the latter appears merely as an appendage at the hilum of the sexual gland.

DEVELOPMENT OF THE PERMANENT KIDNEY.

The first indication of the formation of the metanephros or permanent kidney in man is found before the Wolffian body is fully developed. While Keibel and Hauch describe its first appearance in embryos of 6.5 and 7.5 mm. length, His and Gage claim to have seen it in embryos of 5. and 4.3 mm. length. It seems that Keibel and Hauch referred to the actual appearance of the epithelial bud coming from the Wolffian duct, while His and Gage described the first indication of the formation of the kidney blastema.

The development takes place in two separate stages, a fetal and postfetal stage. While the latter has little influence upon the ultimate form and anatomical characteristics of the kidney, we find that the former determines almost exclusively the subsequent form of the pelvis as well as that of the parenchyma.

I. THE FETAL STAGE.

The Kidney-Anlage and Its Shifting Cranialwards.—The initial stage in permanent kidney formation is clearly noticeable at the beginning of the fourth week, when a delicate bulbous epithelial outgrowth is observed at the lower end of the Wolffian duct. It appears capped by a group of cells, which, according to Schreiner, is a derivative of the lower extremity of the mesonephric blastema, or nephrotom of the Wolffian body, which, as has been shown, did not take an active part in the formation of the tubular system of the Wolffian body. This cap of nephrogenic tissue appears to separate from the blastema of the Wolffian body and becomes the kidney blastema, and from it originates the entire kidney with the exception of the pelvis, calices and collecting tubules, which develop from the epithelial bud growing from the Wolffian duct. The part this kidney blastema plays will be more fully considered later on.

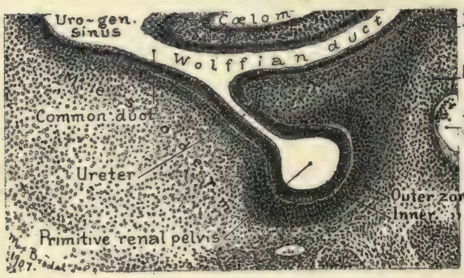


FIG. 54.—SAGITTAL SECTION THROUGH LOWER END OF 5 MM. HUMAN EMBRYO SHOWING KIDNEY BUD.

The original position of the epithelial bud is on the posterior surface of the Wolffian duct shortly before that channel empties into the cloaca, and the direction of its growth is caudal and dorsal (Figs. 55 and 56). The distance from the

anlage to the cloaca and later to the urogenital sinus, measured on the dorsal surface of the Wolffian duct, increases from 0.1 mm. in an embryo of 27 days and 0.2 mm. in an embryo of 32 days to 0.4 mm. in an embryo of 35 days. It then rapidly decreases and at the age of 40 days is *nil,* the renal channel communicating directly with the urogenital sinus. As Fig. 54 shows, this epithelial protrusion is lined by a single layer of cells which are continuous and identical with those of the Wolffian duct. The kidney blastema is clearly seen as a zone of deeply staining epithelioid cells, grouped closely together, surrounded by another zone of condensed mesenchyme, which passes gradually in the mesoderm.

The kidney anlage soon passes through a number of changes, both as to form and position. It grows longer and becomes differentiated into a narrower proximal portion and a somewhat dilated distal pouch. The orifice of the renal channel in the Wolffian duct and that of the latter in the cloaca are subject to a process of shifting which transfers in the first place the orifice of the Wolffian duct from the cloaca in a ventral direction until it opens into the urogenital sinus or allantois. This remarkable process is accomplished by a downward growth of the urorectal septum (Fig. 57), which

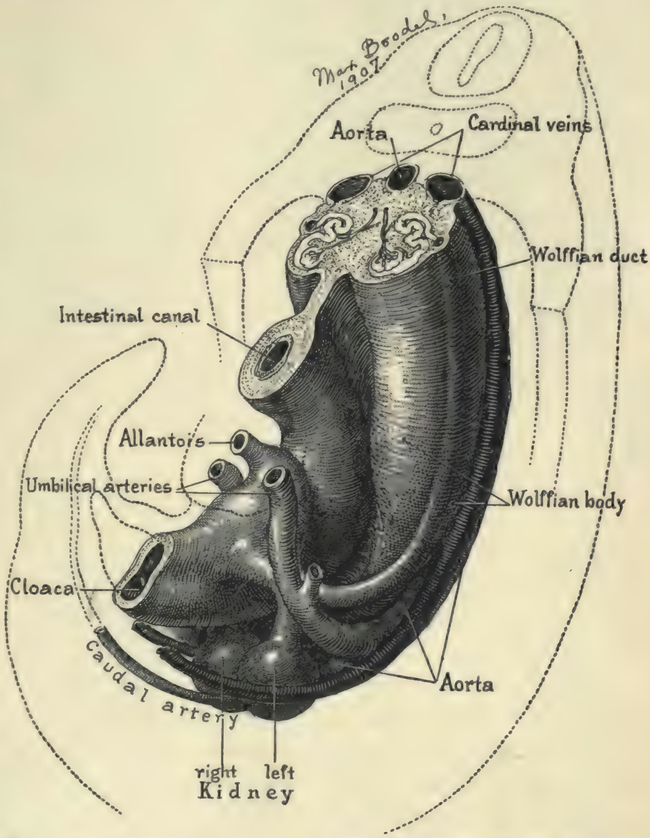


FIG. 55.—RECONSTRUCTION OF THE WOLFFIAN BODY, HUMAN EMBRYO OF ABOUT FOUR WEEKS. (× 40.)

divides the cloaca into two channels, a dorsal and a ventral, forming the rectal and urogenital parts, respectively. The orifice of the Wolffian duct stays ventrally to this dividing septum and opens as a consequence in the caudal portion of the urogenital sinus, the subsequent neck of the bladder. This shifting of the Wolffian duct, however, is only a part of the process, for simultaneously with it

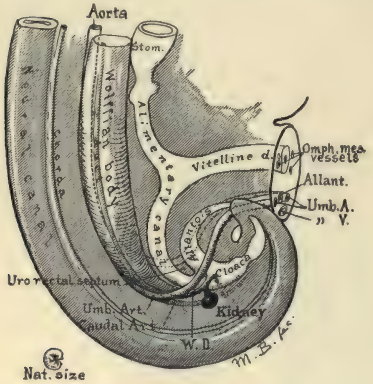


FIG. 56.—THE KIDNEY IN A HUMAN EMBRYO ABOUT 3 WEEKS OLD.

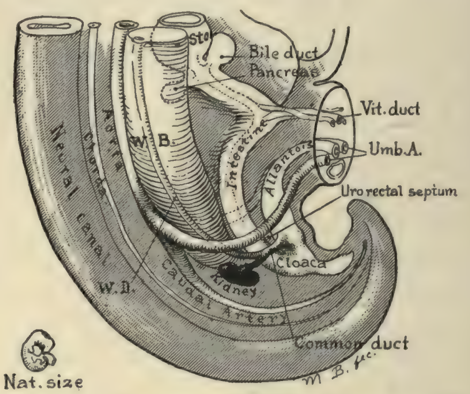


FIG. 57.—THE KIDNEY IN AN EMBRYO ABOUT FOUR WEEKS OLD.

there occurs a shortening and dilatation of the lower end of the Wolffian duct, which seems to become transformed into a part of the urogenital sinus. This portion is termed the common duct, serving as an outlet of both the ureter and the Wolffian duct.

As more and more of the common duct is utilized to form the lateral portion of the allantois, the ureter gets nearer and nearer the urogenital sinus until the openings of the two ducts are separate. It will be remembered that the orifice of the ureter in the Wolffian duct was originally on the dorsal wall of the Wolffian duct; during the above described changes, however, it travels in a semicircle around the outer side of the Wolffian duct until it appears to be situated on its ventro-lateral side, having rotated almost 180 degrees. This is the position of the ureter in relation to the Wolffian duct at the stage when both ducts open separately into the urogenital sinus; i. e., the orifice of the ureter is found lateral and cranialwards to that of the Wolffian duct. This takes place between the ages of 5 and 6 weeks. From this time on the central portion of the dorsal wall of the urogenital sinus develops rapidly in a caudal direction; the Müllerian ducts have joined the Wolffian ducts and open with them into the median portion of the sinus. By this rapid downward growth

the orifices of the Wolffian ducts are shifted with this portion of the sinus a considerable distance caudalwards, while those of the ureters remain in their lateral position (Fig. 60). Wolffian body and sexual gland, attached to its ventral surface, begin to descend, and, having arrived at the level of the pelvis, they are situated lateral to the ureter. As a consequence the Wolffian and Müllerian ducts cross over on top of the ureter at about the middle of its pelvic curve (Fig. 61).

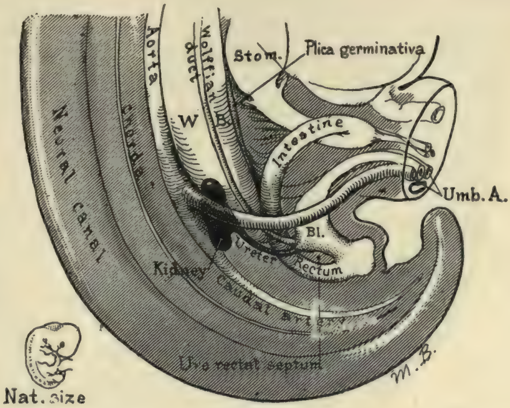


FIG. 58.—THE KIDNEY IN AN EMBRYO ABOUT FIVE WEEKS OLD.

Hand in hand with these changes in the position of the orifice and the course of the ureter, there are also marked changes in the position of the blind end of the renal channel.

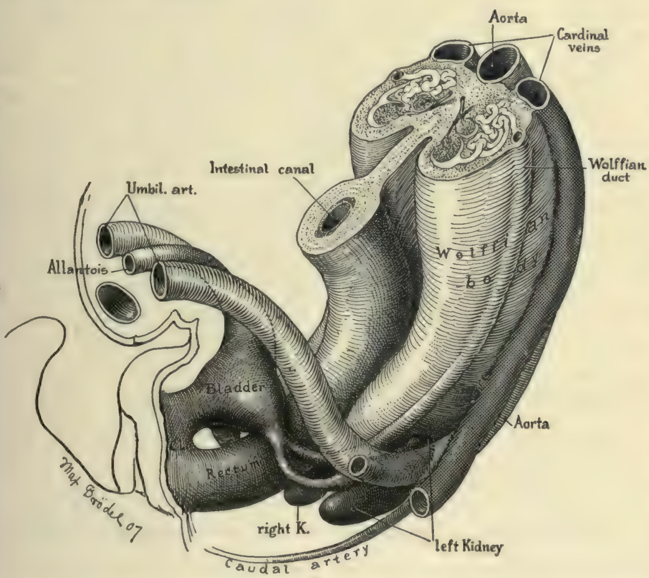


FIG 59.—RECONSTRUCTION OF WOLFFIAN BODIES OF A 14 MM. EMBRYO.

Age 3-4 weeks: Originally the short ureteral stem with its distal pouch comes off at right angles from the Wolffian duct (Figs. 55 and 56). It soon begins to show a tendency to divide into two thick branches, a cranial and a caudal; at the same time the whole anlage shifts cranialwards behind the Wolffian body in a manner shown in Figures 57 to 60.

The umbilical

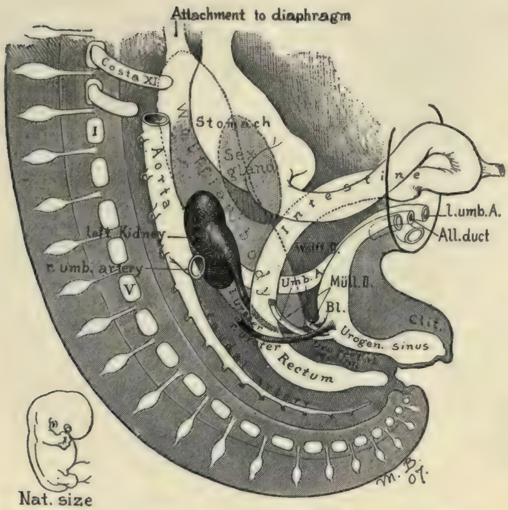


FIG. 60.—THE KIDNEY IN HUMAN EMBRYO ABOUT SIX WEEKS OLD.

arteries are important landmarks in the study of the ascent of the kidney. They are large vessels which are seen to come off from the aorta at almost right angles, after which the aorta continues as caudal artery (Figs. 55-59 and 67). At the age of 3 to $4\frac{1}{2}$ weeks the kidneys lie below the level of the fork formed by the umbilical arteries. The two anlagen are then situated close together with little mesoderm between their mesial surfaces (Figs. 55 and 59). If fusion of the kidneys takes place it must occur before they pass above the level of the umbilical arteries, for they are never again so near each other.

Between the ages of 5 and 7 weeks the kidney shifts past the ring formed by the umbilical arteries, changing from a pelvic into an abdominal organ. During this stage the renal pelvis, or rather the ureter, is still situated on the ventral surface of the kidney (Fig. 67). In passing from the narrow pelvis into the more capacious abdominal cavity, the upper poles lean over laterally, while the lower poles almost touch each other. The pelvis swings slightly medianwards. This topographical position is maintained in adults with horseshoe kidneys, the upper poles far apart, lower fused, arrest of ascent at pelvic brim, renal pelves in front of kidneys and anterior to vessels.

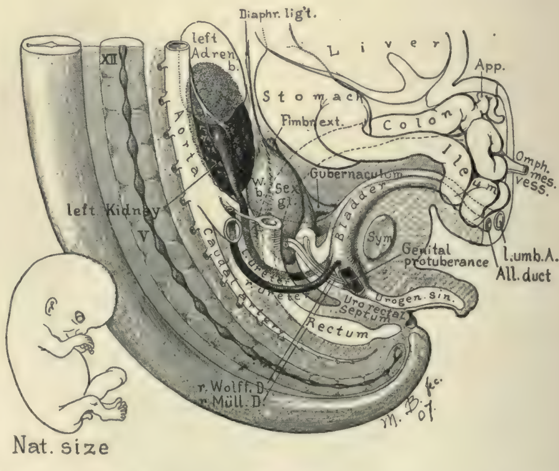


FIG. 61.—THE KIDNEY IN HUMAN EMBRYO ABOUT EIGHT WEEKS OLD.

At the age of 6 weeks (Fig. 60) the greater part of the kidney has already passed the level of the umbilical arteries. The upper pole leans over in a dorso-lateral direction, while the lower poles lie quite near together and more ventral. The Wolffian body shows at this time distinct signs of retrogression and descent,

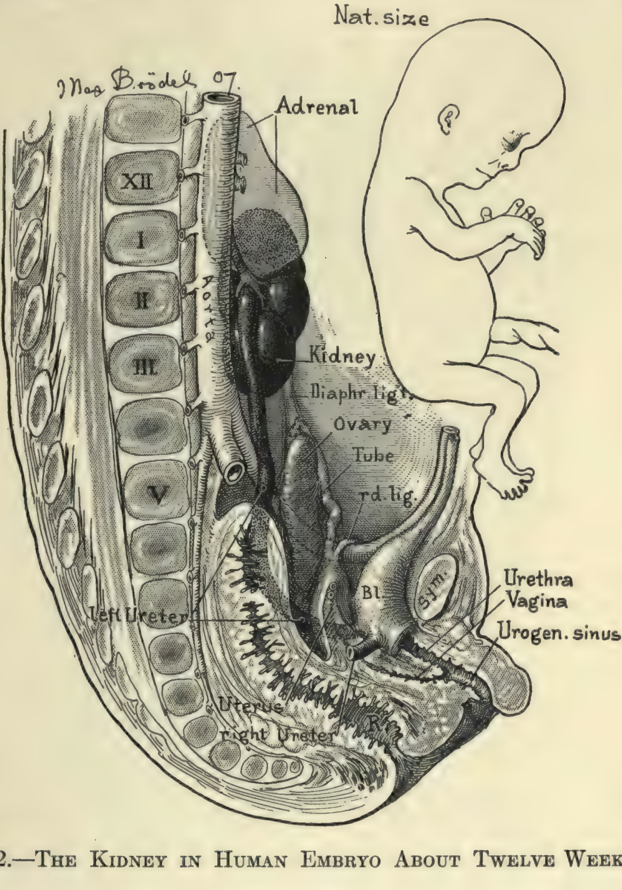


FIG. 62.—THE KIDNEY IN HUMAN EMBRYO ABOUT TWELVE WEEKS OLD.

its upper margin being on a level with the upper pole of the ascending kidney (Fig. 68).

At 8 weeks (Figs. 61 and 68) the kidneys are abdominal organs. Their rotation is completed and the pelvis found at the median surface. During this ascent through the umbilical vascular ring, which is well shown in Figure 67, the position of the organ is to a great extent determined by the shape of the

structures past which it has to travel. In the 6 weeks' stage the axes of the kidney must run more or less parallel to each other owing to the limited space in the pelvis. Higher up the flat surface of the kidney comes to lie against the rounded posterior abdominal wall. There is more room for the kidney in a lateral than in a dorso-ventral direction and for these reasons the rotation

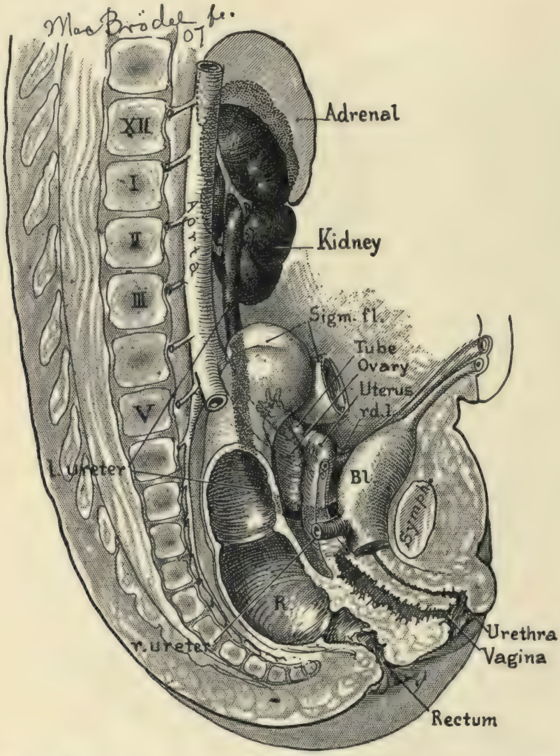


Fig. 63.—The Kidney in Human Embryo About Twenty Weeks Old.

around its long axis is brought about. The lower poles at 8 weeks are established on a level with the lower border of the IV lumbar vertebra, while the upper poles reach up to the I lumbar vertebra (Fig. 61). The kidneys are almost completely covered by the large adrenal body above and the sexual gland and Wolffian body below. The Wolffian body is already much reduced in size and hidden by the sexual gland. The renal pelvis is now situated on the median surface of the kidney; in other words, the kidney has gone through a rotary movement bringing the sinus renalis or hilum toward the vertebral

column. Figure 66 gives a clear idea of this process of rotation and the stages during which it takes place. The axis of the renal pelvis in the earliest stages runs in a ventro-dorsal direction more or less parallel to the median plane of the body, the hilum lies in front. As soon as the kidneys, however, ascend over

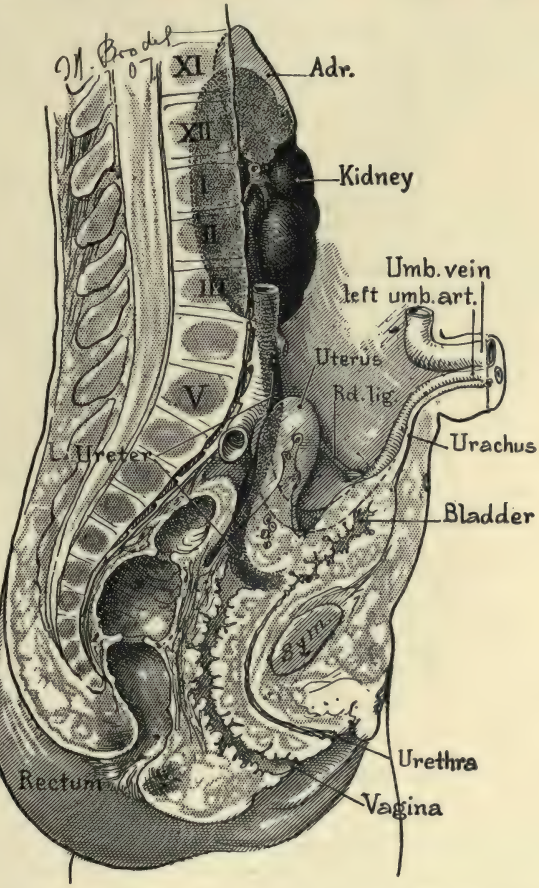


FIG. 64.—THE KIDNEY IN NEWBORN BABE.

the umbilical vessels these axes, now transverse axes of the kidney, lean more laterally until they lose their ventro-dorsal direction completely and are directed straight laterally. This rotation takes place between the 5th and 8th weeks. At about 9 weeks the adrenal body has, through growth of the dorsal abdominal wall, gained a relatively higher level and the kidney becomes visible be-

tween it and the descending sexual gland. On opening the abdomen of an embryo at this stage and removing the tractus intestinalis, the kidney is visible in its lower third or half, with the exception of the outer portion, which is still

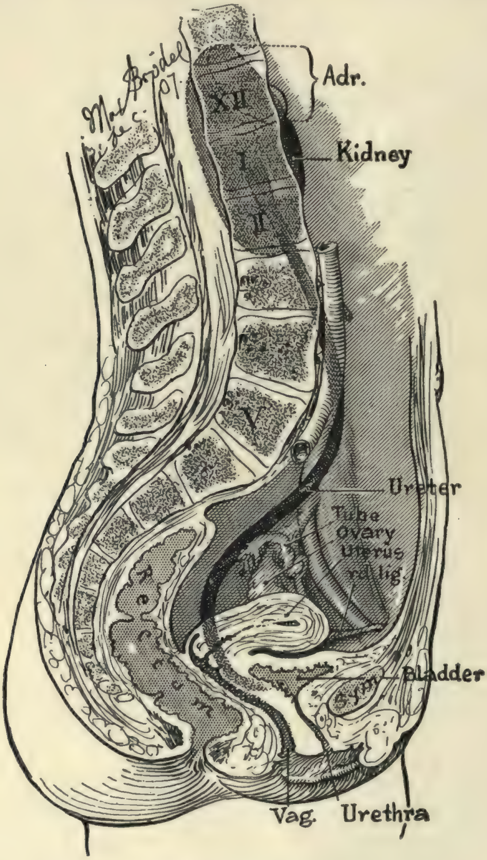


FIG. 65.—THE KIDNEY IN THE ADULT.

covered by the sexual gland. At 10 weeks the kidney is visible almost in its entirety, the adrenal covering only a very small portion of the upper pole, while the sexual gland has descended below the level of the lower pole. The ureter is short and thick. At $11\frac{1}{2}$ weeks the development of the kidney has progressed so much that the adrenal body appears relatively smaller and is situated on top of the kidney like a cap (Figs. 62 and 68). The sexual gland has descended into the pelvis. The ureter is still thick and short, re-

maining so until after birth. There is a marked lobulation on the surface of the kidney. At the age of 12 weeks (Fig. 62) the lower pole of the kidney is at a level with the upper border of the IV lumbar vertebra or lower border of the III, at which level it remains until birth. The growth of the kidney, however, causes the upper pole to ascend until the maximum height is attained, at the age of 5 months. Thus, we find the upper pole at the age of 12 weeks on a level with the XII rib and at the age of 20 weeks as high up as the XI rib (Fig. 63). The appearance of the abdominal organs

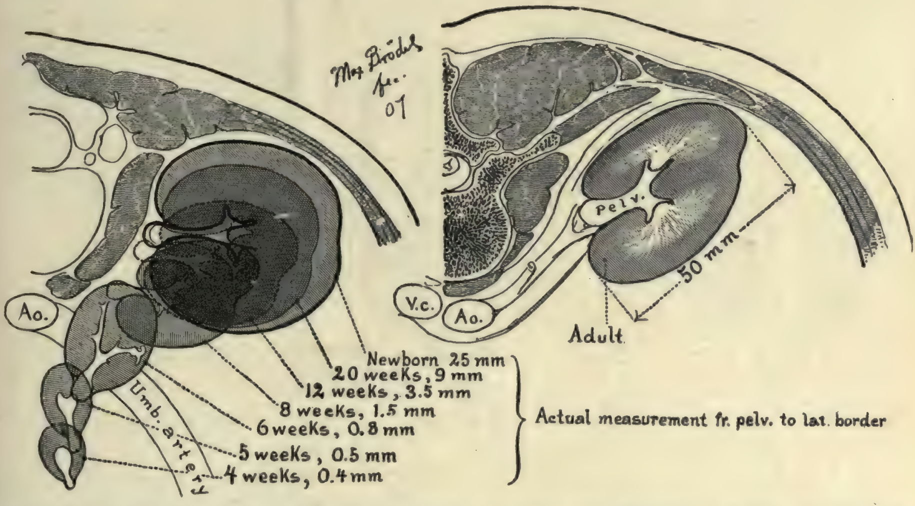


FIG. 66.—THE CHANGE OF THE TRANSVERSE AXIS OF THE KIDNEY. Figure to the left shows change from fourth week to newborn; that to the right, the adult.

is now quite similar to that found in the adult. The kidneys are strongly lobulated and are visible with the exception of their upper poles, which are partly covered by the adrenal bodies. At term the kidneys reach from a level between the III and IV lumbar vertebræ up to the XI thoracic vertebra (Fig. 64). Their topographical relation is still almost the same as that of the kidneys in a 12 weeks' embryo.

The changes in the position of the kidneys until they have attained the place they hold in the adult are best understood by studying the last figure in the series illustrating the ascent of the kidney (Fig. 65). The upper pole remains where it was in the 20th week of intrauterine life, but the lower pole has ascended and is found on a level between the II and III lumbar vertebræ.

This ascent, however, is only apparent, for it has its cause in the relatively slower growth of the kidney as compared with that of the rest of the body, especially the trunk. To appreciate this one need only recall the fact that the two kidneys of the newborn represent 1-80 part of the weight of the body, while those of the adult weigh only between 1-240 and 1-280. While in the adult the kidney becomes relatively smaller, the ureter increases considerably in length, although it is relatively thinner in the adult than in the newborn. The position of the two ends of the ureter is determined by the kidney and bladder, so we find that on account of the backward rotation into the lumbar

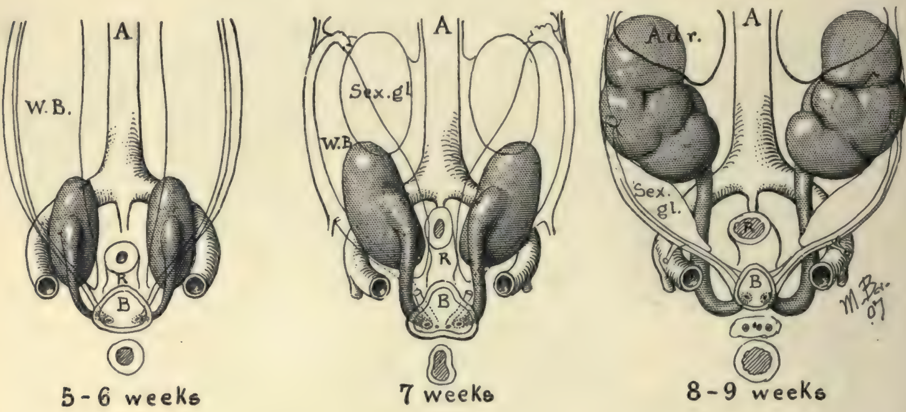


FIG. 67.—DIAGRAMS SHOWING THE ASCENT OF THE KIDNEYS OUT OF THE PELVIS. Note how at first the renal pelves are in front; later turned toward the mid-line, finally turned posteriorly. Fusion of the lower poles at 7 weeks produces horseshoe kidney.

niches the upper end is carried backward, while, on the other hand, owing to the descent of the pelvic organs and with them of the base of the bladder, the lower end of the ureter is brought backward and downward. The middle portion stays well anteriorly, or, if anything, becomes still further pushed forward, owing to the lumbar curve of the vertebral column and growth of the M. psoas. All these factors combined serve to give the ureter the pronounced sigmoid curve it has in the adult (Fig. 65).

The position of the kidney in its niche is very different in the adult from what it is in the newborn. Aside from the fact that it has become much smaller in proportion to the body, there is a decided difference in the position of its transverse axis (Fig. 66). While the axis of the kidney in the newborn is directed almost straight laterally, that of the adult leans backward in a varying

angle, the extent of which depends upon the depth of the paravertebral niches into which the kidneys swing back around an axis represented by the aorta.

Fusion of kidneys, abnormal growth and position, as well as ascent, are better appreciated after a careful study of this shifting of the kidney-anlage. If kidneys have grown together they are generally found at the aortic bifurcation. The fusion is generally confined to the lower poles, which form the bridge of the horseshoe kidney. This bridge may be a narrow fibrous band or a broad strip of cortical substance. However, there are cases where the kidneys are fused in their entire length (scutiform kidney or shield kidney and lump kidney or *ren informis*), an occurrence which must have taken place during the pelvic stage. The fusion is confined to the parenchyma, while the pelves remain separate, the ureters passing over the ventral surface of the fused organ. Like the horseshoe kidney, such kidneys remain at the level of the aortic bifurcation. The pelves of fused kidneys are always in front and the arteries are derived from the nearest arterial trunks, i. e., from the lower part of the aorta, in one common or two separate vessels, and from the iliac arteries. The arteries enter the renal parenchyma either from behind or curve around the lateral border in order to plunge into the kidney substance somewhere near the pelvis. The kidney, therefore, has preserved the position it occupied at the sixth week of fetal life. Although failure to ascend is generally found in cases of fused kidneys, there have also been observed single kidneys which had never ascended above the aortic bifurcation or iliac fossa; or they may be even as far down as in front of the I and II sacral vertebræ. Such kidneys always have their hilum in front and their vessels coming from the aorta near its bifurcation or from the iliac vessels. These conditions signify that the organ has, in so far as its position is concerned, never passed beyond the fifth or sixth week's stage. The peculiar abnormal arrangement of the vessels in such kidneys opens up the very interesting question as to the time and manner in which the arteries wander into the newly formed organ.

Development of the Renal Vascularization.—The development of the permanent renal ARTERIES takes place between the 7th and 8th weeks, consequently at a time when the kidney has already shifted into the position in relation to the aorta which it maintains in its essentials throughout life (Figs. 67 and 68). Previous to that stage the kidney receives no direct branches from the aorta. As Dr. Jeidell (anatomical laboratory of the Johns Hopkins University) has shown, the capillaries of the kidney bud probably communicate with the capillaries of the neighboring regions as the kidney passes upward. New capillary anastomoses are thus formed at the upper pole as it ascends, while those at the lower pole atrophy. A crude comparison of this process would be the

movements of arms and legs of a person climbing a ladder. The vascularization of the lower end of the ureter appears to develop from the plexus around the Wolffian duct and allantois. It is probable that the ureter and pelvis receive their vascularization first in this manner, as it remains practically independent from the parenchymal circulation in the adult. The character of these vessels is also quite different from that of the kidney vessels proper. They are long

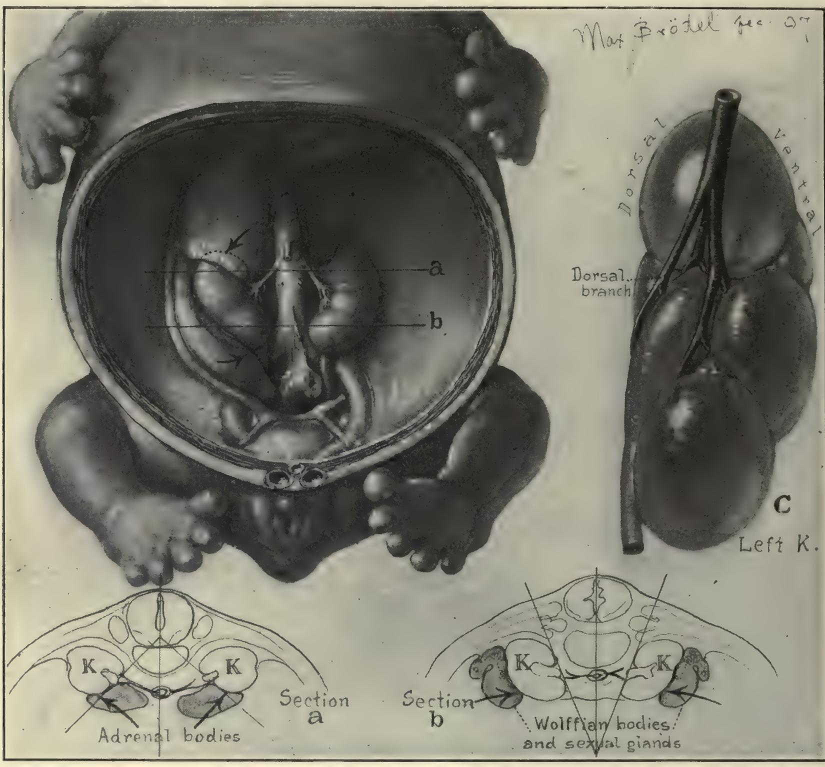


Fig. 68.—Human Embryo 25 mm. in Length, Showing Characteristic Position of Kidneys at the Time Its Permanent Vascularization is Formed.

and tortuous, anastomosing with the vascular systems of the neighboring structures and the base of the bladder. After the kidney has reached its final position, the capillary channel, which is in the most favorable position in regard to the parenchyma, enlarges to become an artery, or, if the kidney is complex in form, has a double pelvis, etc., two or more separate channels survive. The point of origin of the renal arteries is about at the level with the II lumbar

vertebra, and, as the hilum of the kidney at the age of 7 weeks is about at the level of the III and IV lumbar vertebræ, the arteries have to pass in an oblique direction downward, resembling the course of the Wolffian body arteries (Fig. 68). The hilum at this stage has a peculiar twisted position, representing about one-eighth of a spiral turn, the upper portion facing more ventrally, while the lower portion is directed dorsally. This is probably due to

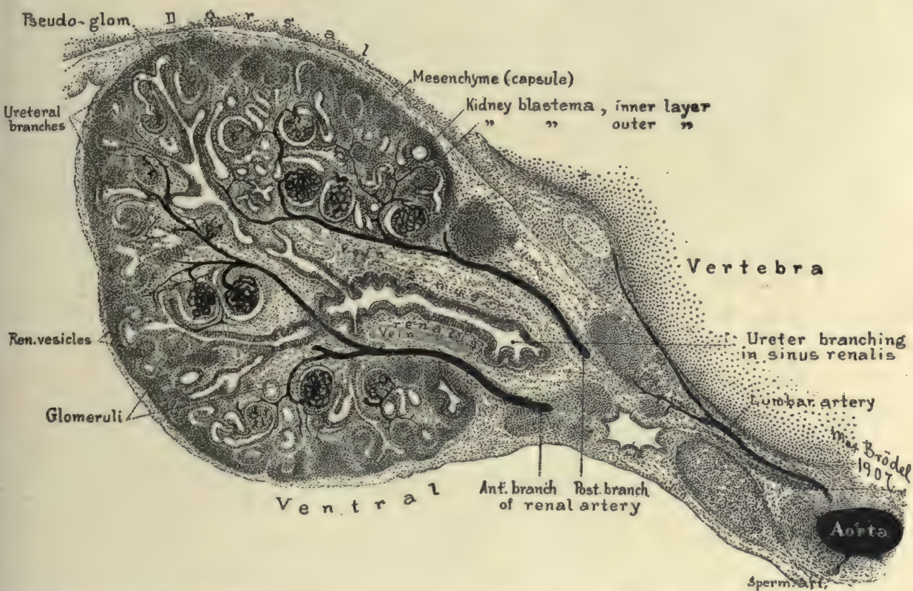


FIG. 69.—TRANSVERSE SECTION THROUGH KIDNEY OF 9 WEEKS' HUMAN EMBRYO, SHOWING EARLY STAGE OF ARTERIAL VASCULARIZATION.

the position of the adrenal body, which prevents the anterior half of the upper pole from swinging over toward the median line (Fig. 68a), and to the Wolffian body and sexual gland, which bring their pressure to bear on the outer portion of the lower pole. As a consequence, the pelvis at the hilum has an oblique direction, from above anterior to below posterior. The renal artery, shortly before the pelvis is reached, branches into several twigs which invade the undifferentiated connective tissue of the sinus renalis. They run between the pelvis and the newly formed parenchyma, however, much closer to the latter, the pelvis acting as a dividing wall for the developing arterial trees.

As Figure 68c shows, the ventral portion and upper and lower pole of the kidney are more easily accessible to the arterial branches, while the lower

dorsal portion is at a decided disadvantage in this respect. The arterial branch supplying it has to curve around the upper posterior margin of the pelvis in order to reach the parenchyma which it is to supply. There is no other way of reaching this portion of the kidney from the aorta, and it is for this reason that this dorsal branch with its characteristic course, skirting the pelvis posteriorly, is found with such regularity in all cases.

If the kidney is of unusual length or if there is a divided pelvis or double ureter, the aorta displays a tendency to supply the organ with more than one artery, usually two, but in exceptional cases there have been seen as many as five separate arteries. A supernumerary artery may enter at any point along the median surface of the kidney, preferably the upper pole.

Figure 69 shows the manner in which the arterial twigs invade the kidney. The pyramids have not yet formed and the parenchyma consists only of the kidney blastema, through which the ureteral branches advance toward the surface. There are but few of them, as their rapid branching does not occur until a later date. They lie embedded in the connective tissue of the sinus renalis, and when they have reached the cortical zone they are seen to plunge into the same, accompanied by a small amount of connective tissue, which appears continuous with that of the sinus renalis. The cell groups of the cortex are by these advancing tubules divided and subdivided into smaller groups, in which the pseudo-glomeruli are formed. These are supplied with vascular twigs and transformed into glomeruli. As the arteries pass along the inner surface of the cortical shell the innermost region receives the first set of glomeruli (Fig. 69). The crescent-shaped lumen of the glomerulus is situated nearest the center of the kidney and the arterial twigs enter the glomerulus at the side opposite the lumen; i. e., at the point furthest removed from the main arterial twig. So the afferent vessels are often seen describing a semicircle around the glomerulus before entering it. The advance of the circulation from within out and the formation of glomeruli go hand in hand, and the glomeruli at the surface and in the central layer of the columns of Bertin are always the youngest.

The arterial system forms in two trees, a larger anterior and a smaller posterior. The anterior generally gives rise to the branches of the upper and lower poles (Fig. 68c), the posterior rarely contributing branches to the lower pole. The position of the kidney at the time the vessels develop has great influence upon the relation of the anterior to the posterior trees. The anterior parenchyma lies, as a rule, much nearer the aorta than the posterior, and the advancing arterial branches consequently become sooner established in the anterior parenchyma than in the posterior. The anterior glomeruli are more numerous

and quite advanced in development before the posterior begin to form, and when the two arterial trees meet on the lateral border of the kidney the anterior system has traversed a longer distance inside the parenchyma than the posterior, upon whose territory it has begun to encroach (Fig. 70). The line of division between the two arterial trees is then in the posterior half of the kidney.

This, however, is only a part of the process producing the remarkable relationship between the two arterial trees. The considerable preponderance of the anterior system over the posterior has its main cause in the formation of the longitudinal cortical column, or wedge of cortical substance which, similar to the columns of Bertin, grows from the surface down into the sinus renalis. The situation of this long column is an equal distance away from both sides of the hilum, the anterior and posterior (see Fig. 70, lower diagram), for reasons to be stated when describing the growth of the cortex. Because the posterior portion of the parenchyma is receding from the mesial line of the

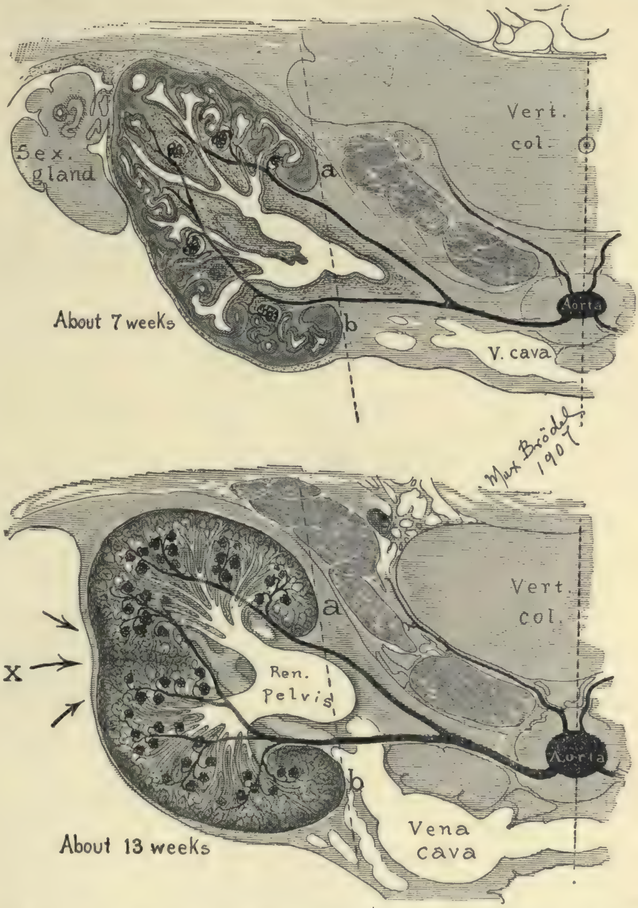


Fig. 70.—Diagram of Transverse Sections Showing Development of Most Frequent Arterial Distribution. Note the larger area supplied by the anterior artery. X indicates wedge of cortex growing in, always equidistant from *a* and *b*.

body, the long column (X) passes, not along the lateral border, but nearer the anterior surface of the kidney, and so comes to lie in the territory of the anterior arterial tree, between whose branches it wedges its way down to the sinus renalis. This being the natural, and therefore more frequent position of the kidney at the time the blood vessels develop, we find this type present in three-fourths of cases in the adult. The reversed condition is found in cases where the anterior parenchyma recedes from the middle line, while the posterior parenchyma projects nearer into its vicinity (Fig. 71). The pelvis is then in front instead of behind the kidney, and the longitudinal cortical column wedges itself into the larger posterior arterial tree. The majority of vessels pass in such kidneys behind the pelvis and the posterior arterial tree overlaps into the anterior portion. Between these two extreme conditions there are numerous intermediate forms, all of which have their explanations in the manner in which the kidney blastema and the renal pelvis with its branches were placed in relation to the aortic trunk

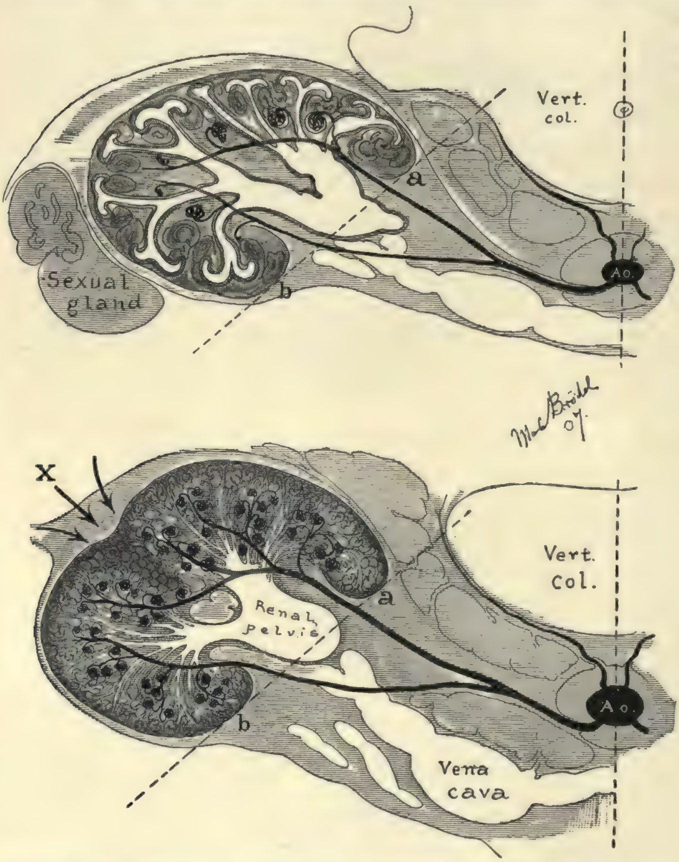


Fig. 71.—Diagram Showing Development of a Reverse Condition, Upper Diagram 7 Weeks, Lower Diagram 13 Weeks. Note the greater area supplied by the posterior artery. X indicates wedge of cortex growing in, always equidistant from *a* and *b*.

at the time the blood vessels developed. This determines the point of entrance for the vessels and the position of the cranio-caudal plane where their terminal branches are found. If a kidney has not undergone the rotary motion, its pelvis is found on the anterior surface. The blood vessels are then seen to enter the parenchyma from behind the pelvis at points nearest the aorta. Similar abnormal growth of the arteries is found in all cases of abnormal position of the kidney.

The pelvis and parenchyma precede in their formation that of the blood vessels, which simply adjust themselves to the positions of the preexisting parts. They arise from the nearest aortic sources and enter the kidney at the most convenient point or points.

Inside the kidney the arteries remain at first in a rather unbroken row on the inner surface of the cortex (Fig. 72), none of them coming into the vicinity of the branching ureter, later pelvis. Quite different, however, is the course and distribution of these same arteries in the adult, where a good many of them, in fact, the largest, are found in the center of the kidney in the immediate vicinity of the pelvis. This dislodgment is brought about by the inward growth of the cortex, which carries the blood vessels with it into the depth. The deeper these columns of Bertin are, the nearer the pelvis we find the larger vascular trunks (Fig. 72).

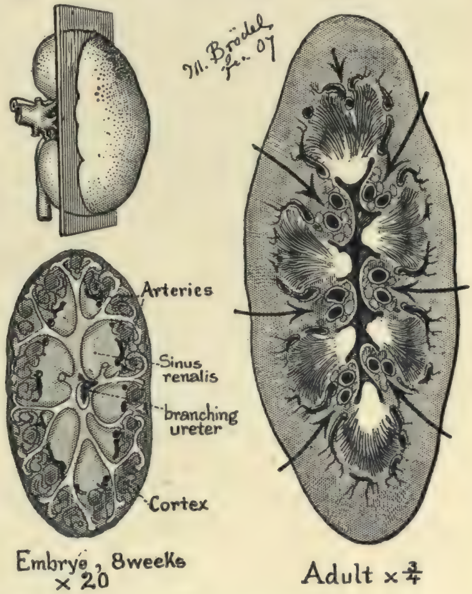


FIG. 72.—SECTIONS TAKEN AS SHOWN BY SMALL DIAGRAM IN UPPER LEFT-HAND CORNER. Note in embryonic kidney that the ring of arteries forms an unbroken line at inner surface of cortex. In the adult the cortical columns represented by arrows carry a part of the vessels down close to the pelvis, breaking the continuous line.

The rest of the large blood vessels remain at the base of the pyramids, the pyramidal substance developing through their meshes and pushing its way towards the center, forming the papillæ.

The VEINS of the kidney are found in the sinus renalis between the arterial

branches and the pelvis (Fig. 73). All the capillaries of the parenchyma drain as a rule in one venous system, which passes in front of the pelvis. At the upper and lower poles, however, there are also collecting branches on the posterior side. These communicate at first along the posterior side of the hilum, but atrophy in the majority of cases, and in the adult we rarely find a large vein in this region, the blood of the posterior half preferring the more direct

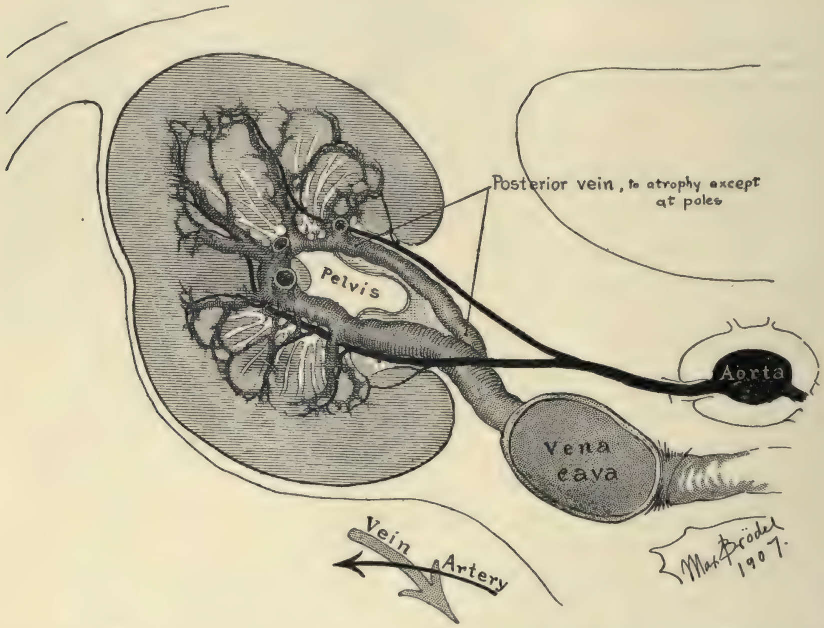


Fig. 73.—The Development of the Venous System in the Sinus Renalis Between the Arteries and the Pelvis. Note crossing of the artery and vein at region of hilum.

channels; i. e., between the calices to the anterior system and from thence to the vena cava. Inside the kidney the veins are situated centrally to the arteries, while the vena cava is found in front of the aorta. Therefore, we find that, in order to reach the vena cava, the vein or veins have to cross the arteries (see Fig. 73).

The development of the venous system of the trunk is of considerable interest in the study of the renal veins. The four well-known diagrams of Kollmann (Fig. 74) illustrate the different steps very clearly. The changes are rapid and in embryos of 11 mm. length the third stage is already found. In the early form of the venous system we have the two cardinal veins running along

the dorsal surface of the Wolffian bodies (Fig. 74 I, and Figs. 52, 55 and 59). Its tributaries are:

1. The veins of the segments of the abdominal wall and of the medullary tube.

2. The veins of the Wolffian body, numerous short branches which empty into the mesial side of the cardinal vein.

3. The two veins of the vertebral tail, which are really the roots of the cardinal veins.

4. Somewhat later the ischiadic vein.

After very short duration this arrangement is completely altered through the development of the portal vein and the vena cava. The latter makes its appearance between the Wolffian bodies in the form of two parallel trunks, collecting blood from the Wolffian bodies. They are known as the subcardinal veins. These two vessels are connected by a transverse channel, which soon enlarges. The left trunk, with the exception of a few unimportant twigs, becomes rudimentary, while the right increases and communicates with the liver (Fig. 74, second diagram).

This large vein now anastomoses laterally with the two cardinal veins, whose caudal portions thus change into tributaries of the vena cava. The cranial portions become transformed into the Vs. azygos.

The next step is the formation of a pelvic anastomosis between the two cardinal branches of the vena cava (Fig. 74, third diagram), situated just ventral to the middle sacral artery, as a consequence of which the left cardinal branch partially disappears, the blood finding the anastomosis and right cardinal branch a more convenient channel. All that remains of the left cardinal branch are the upper portions, to which the renal veins become attached and into which the veins of the sexual gland and adrenal body drain (Fig. 74, fourth diagram). The veins of the Wolffian body gradually disappear as the organ descends and diminishes in size; only a few small veins at the cranial portion remain in the service of the adrenal body. The last stage (Fig. 74, fourth diagram) has been reached already at the seventh week of embryonic life and with it the permanent venous circulation is established.

The medullary substance begins to develop rapidly after the vascular system at the inner surface of the cortical substance is fairly well advanced. The ureteral branches continue to divide and at the same time the loops of Henle begin to form. They dip down among the ureteral branches and as their number and extent increase they press upon the ureteral branches, whose lumen is thus narrowed down to the caliber of which it is seen in the subsequent ducts of Bellini. This growth takes place from the already established cortex,

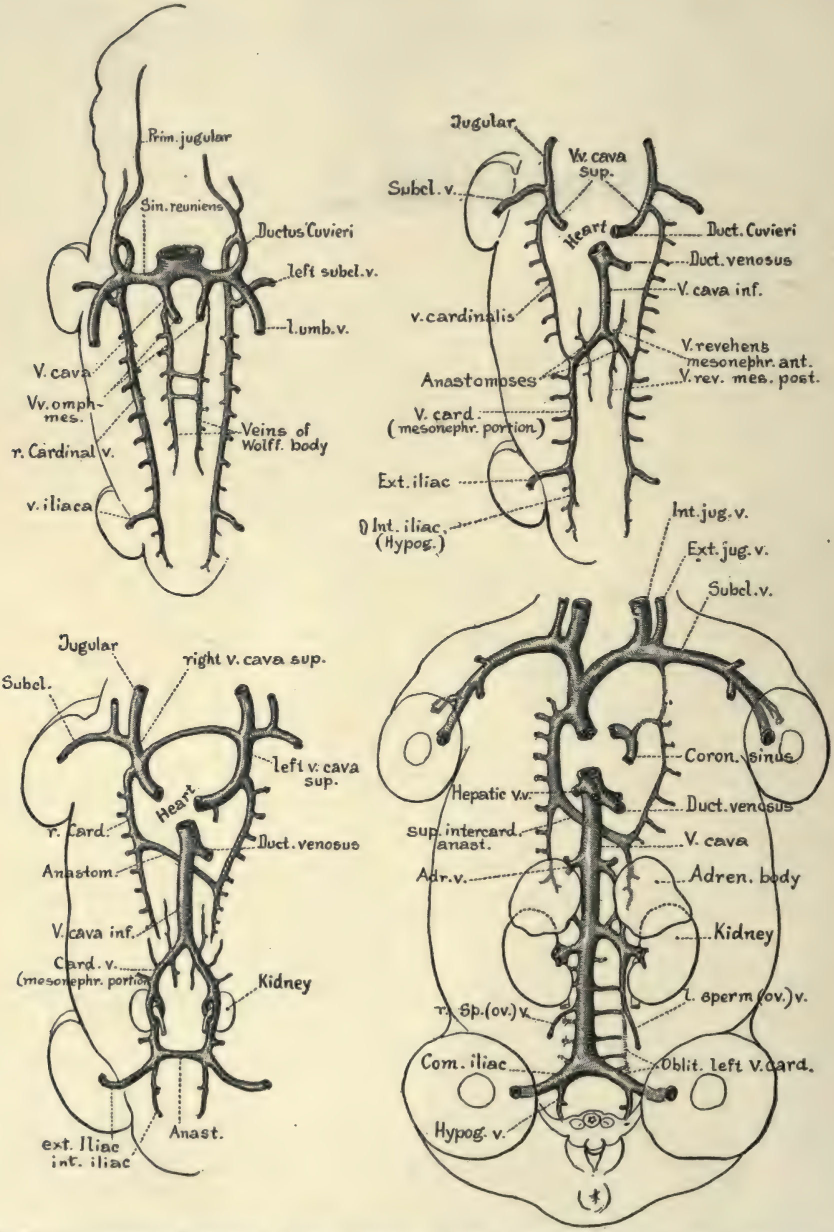


FIG. 74.—DIAGRAMS SHOWING DEVELOPMENT OF THE VENOUS SYSTEM WITH REFERENCE TO THE KIDNEY. (Redrawn After Kollmann.)

through the meshes of the main vascular zone, into the central connective tissue zone, the sinus renalis, and this process marks the beginning of a pyramid. In this manner the circulation of the gland is established between the cortical and medullary substances. Together with the inward growth of the medullary substance, or even preceding it, there is a very marked growth of the cortex, which is the principal factor in the establishment of the subsequent form of the pelvis and of the entire organ. Before, the kidney possessed only one pyramid with one unbroken outer zone of cortex; after this cortical ingrowth in certain intervals, the original single pyramid becomes divided and subdivided until the gland consists of seven or more well-defined pyramids. This process will be more fully considered in the next section.

Development of the Ureteral Branches and of the Kidney Blastema.—The growth of the ureteral branches in the kidney blastema has great influence upon the ultimate form of the kidney, and as they affect each other considerably in their growth, a description will have to take up both simultaneously.

The structures composing the kidney are derived from two sources: (1) the epithelial protrusion from the Wolffian duct, and (2) the kidney blastema (see Fig. 54) surrounding the dilated end of this epithelial channel. The old controversy as to the part these two elements play in the make-up of the kidney has been put aside by the careful studies of G. S. Huber (*Am. J. Anat.*, 1904-5, iv, suppl., 1), who shows that the epithelial bud at the lower end of the Wolffian duct gives rise to

Ureter,
Pelvis,
Calices,
Papillary ducts,
Collecting tubules,

while the cells of the kidney blastema form the origin of

Convoluted tubules,
The loops of Henle,
Bowman's capsules,
Glomeruli.

At the age of about 27 days (Figs. 54 and 75) the kidney blastema is an oval group of cells which completely envelops the blind end of the ureteral channel. It is fairly well differentiated from the mesoderm, surrounding it on all sides, although in some places the cells of one seem continuous with those of the other.

The cells of the kidney blastema are grouped much more closely together than those of the mesoderm, their individual form is oval, and their nuclei stain much darker than those of the cells of the mesoderm.

As soon as the newly formed organ begins to ascend behind the Wolffian body the blind end of the ureter commences to branch into an upper and lower pocket. These again send off new branches into the adjacent kidney blastema

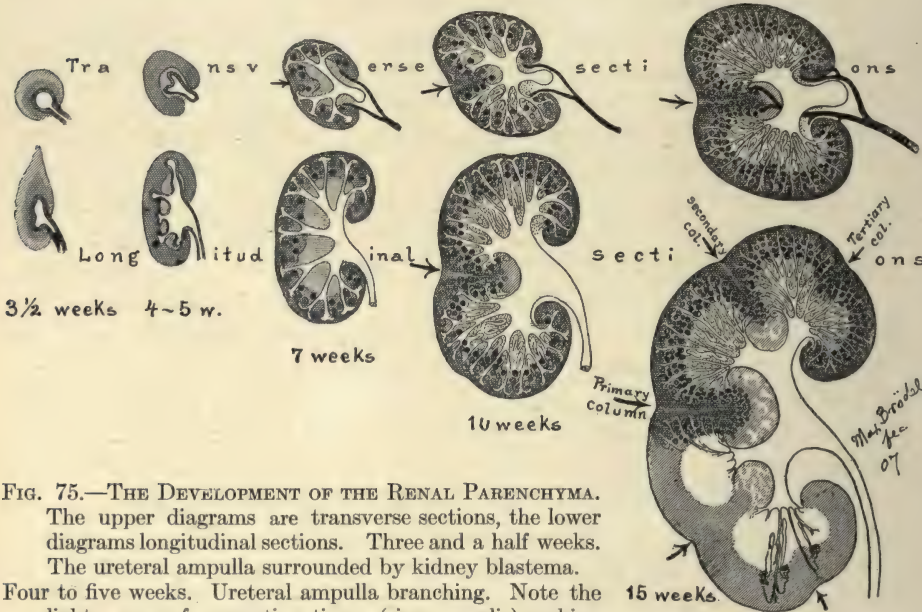


FIG. 75.—THE DEVELOPMENT OF THE RENAL PARENCHYMA. The upper diagrams are transverse sections, the lower diagrams longitudinal sections. Three and a half weeks. The ureteral ampulla surrounded by kidney blastema.
Four to five weeks. Ureteral ampulla branching. Note the lighter zone of connective tissue (sinus renalis) making its appearance between the branching ureter and the kidney blastema.
Seven weeks. Ureteral branches traversing sinus renalis in greater numbers. Note their end ampullæ just under the surface. First sign of glomeruli in central zone of cortex. Pseudo-glomeruli in periphery. Kidney up to this stage shows no division into lobes.
Ten weeks. Increased number of ureteral branches. Division into four groups, upper ventral and dorsal, and lower ventral and dorsal. This arrangement is due to a longitudinal and a transverse wedge of cortical substance pushing their way into the sinus renalis, as shown by arrows. These are the first indications of the subsequent columns of Bertin.
Fifteenth week. Great number of ureteral branches. Their lumina are much reduced owing to their greater numbers and on account of the loops of Henle growing down from the cortex between the collecting tubules. We have thus the beginning of the medullary substance. The cortex continues to increase in volume, making room for itself in an outward as well as an inward direction. New wedges of ingrowing cortex are formed in this manner, subdividing the groups of ureteral branches (calices), whose number thus increases to six or eight. The primary cortical columns are the deepest, the secondary less deep, and the tertiary quite shallow.

until after 2-4 dichotomous branchings the end-channels number from 15-20. Occasionally one channel may send off more than one secondary branch, which explains the somewhat irregular sum of end branches after four branchings. These canals are relatively wide and extend almost to the surface, where they

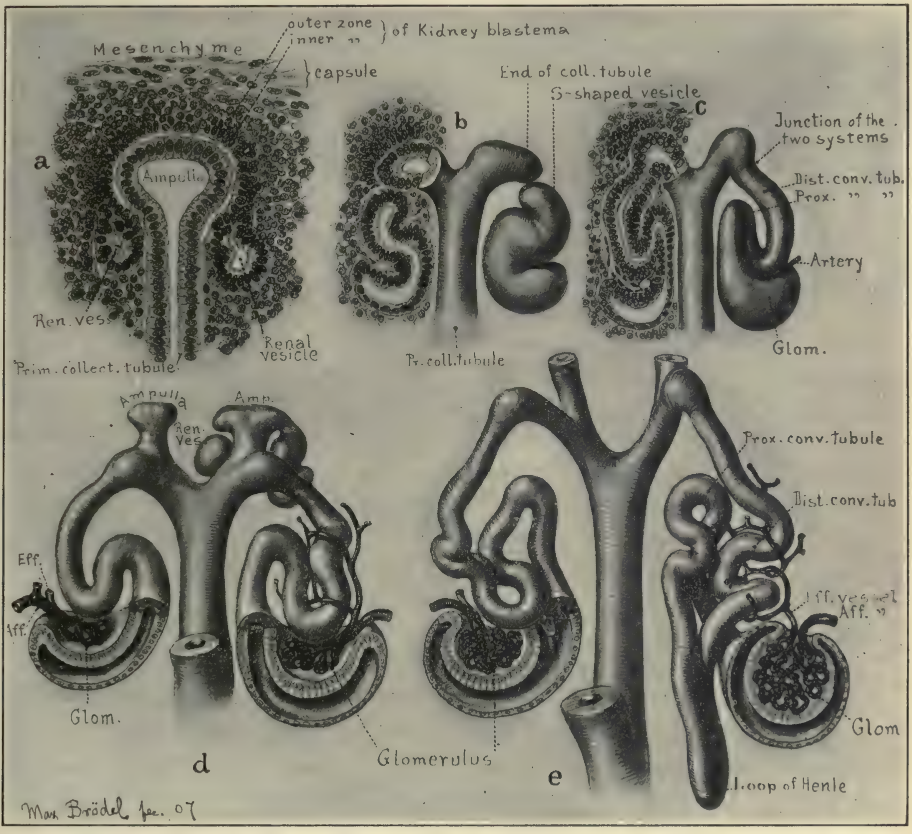


FIG. 76.—THE DEVELOPMENT OF THE KIDNEY TUBULES. (After Huber.)

distend in form of a Y-shaped ampulla. The kidney blastema envelops these ampullæ in a characteristic manner (see Fig. 76). There is an inner zone of cells with deeply staining nuclei grouped very closely together. This is surrounded by a less dense zone of cells, staining less deeply. Peripheral to this blastema there is a thin layer of mesenchyme, which is easily recognized by its spindle-shaped cells; from this layer the capsule of the kidney is formed.

Outside the mesenchyme the loose-meshed embryonic mesoderm can be distinguished.

From the inner zone of the blastema, or nephrogenic tissue (Huber), in the angle between stem and ampulla, develop the RENAL VESICLES (see Fig. 76a). They are at first aggregations of cells, which gradually acquire a lumen. As Huber has conclusively proven, they do not communicate with either ampulla or tubule until they have developed into a short S-shaped structure (see Fig. 76b). As these diagrams show, the upper portion of the renal vesicle, that nearer the periphery of the kidney, develops into the convoluted tubule and loop of Henle, while the lower gives rise to the glomerulus.

While the first generation of convoluted tubules and glomeruli is thus formed, the ureteral branches continue to advance and divide, forming new ampullæ (Fig. 76d). As they push toward the periphery, the kidney blastema accompanies them, always covering the ampullæ like a cap. The process of the formation of renal vesicles is repeated. In this manner the different generations of convoluted tubules and glomeruli are produced, the youngest generations always being at the periphery, and between it and the capsule the last formed ampullæ of the straight tubular branches, capped by the kidney blastema.

At six weeks the ureteral branches have divided 4-5 times and the end branches number about 20-30. The characteristic end-ampullæ just beneath the peripheral layer of kidney blastema cause the peculiar mottled appearance of the surface of the kidney of about 7-9 weeks when examined with a low-power lens (Fig. 61). These spots have nothing to do with the lobulation of the surface, which appears at a later date.

The division of the ureter is such that one portion of the branches invades the cranial half of the kidney blastema, another portion the caudal. There is also a certain tendency toward a division in a dorsal and a ventral system. However, this division of the ureteral branches into groups does not come very clearly into view until the cortical layer begins to grow into the kidney in the form of the columns of Bertin.

The ureteral branches continue to divide in the connective tissue center of the kidney and at the age of 8 weeks there are about 50-60 terminal branches, produced by five consecutive branchings (Hauch). This is not always dichotomous, but often one branch divides into 3-4 new ones, which again may divide soon afterward. Between these branches is the undifferentiated connective tissue of the sinus renalis, which can be readily distinguished from the parenchyma occupying the periphery. The lumen of the ureteral branches is large and quite uniform and there is no dilatation at the points of division.

The inner convoluted tubules of the future kidney have by this time developed, likewise the future glomeruli. They have as yet no vascularization, and appear, therefore, small. However, they show already a crescent-shaped lumen, the parietal wall of which possesses cuboidal epithelium, while the visceral portion has high cylindrical epithelium. Since they lack vascularization, these formations have been called pseudo-glomeruli. Their transformation into actual glomeruli begins between the ages of 7 and 8 weeks through the growth of vascular loops into the visceral portion of the pseudo-glomerulus. We have already mentioned the peculiar arrangement of the glomerulus in relation to the vascular center. The crescent-shaped lumen of the pseudo-glomerulus is nearest the arterial source, and the afferent vessel as a consequence is compelled to curve half way around the body of the glomerulus before it is able to enter its interior (Figs. 69 and 76).

At first the pseudo-glomerulus is shallow, with the end-ampulla of the convoluted tubule distended; as soon, however, as a vascular loop enters it the blastema cells increase, new loops of vessels develop, and the flat body soon becomes spherical, pushing its way into the lumen of the end-ampulla of the tubule, which in this manner is gradually caused to surround the vascular labyrinth on all sides.

The tubules are at first quite short, as in Figure 76, and quite simple in construction. Later in the development of the kidney they form extensive convolutions and one portion dips down to give rise to the loops of Henle.

The pseudo-glomeruli have at first an irregular arrangement, but later group themselves in three layers, a central, middle, and peripheral; the central glomeruli being in the most advanced state of development. During the entire development of the cortex this method of growth is maintained, the central glomeruli always being the oldest and those peripherally situated the youngest. Between the ages of 8 and 9 weeks these three layers of glomeruli are crossed by the radiating outgrowths of the ureteral branches and subsequently by the loops of Henle growing in an opposite direction. This causes a compression and subdivision of the groups of glomeruli, and, because of the straight course of the renal channels, the glomeruli are forced to assume a more or less regular arrangement. They are then seen in rows of 2-4, running at right angles to the surface (Fig. 75).

When describing the growth of the blood vessels it was noted that the central glomeruli are the first to receive their blood supply. They increase both in number and size in a manner rendering the space provided for them inadequate. They are walled off peripherally by the solid layer of undeveloped

parenchyma, consequently there is small chance to grow in this direction. The only way in which they can spread out freely is laterally and inward, in a direction of least resistance. This is indeed what takes place. We find the cortex bending from the poles upon the pelvis, so as to reduce the hilum to a very small oblique slit. At the middle of the lateral border the cortex likewise expands in the direction of least resistance, which is toward the sinus renalis in the center of the organ (Figs. 75 and 77). A similar ingrowth is seen on transverse section, and we find that there is a longitudinal column of cortical substance, which pushes its way toward the center of the kidney, dividing the ureteral branches into an anterior and a posterior set (see Fig. 75). We have thus the beginning of the formation of renal lobes. There are at first four of them: Cranio-ventral, cranio-dorsal, caudo-ventral, caudo-dorsal. Between them are the primary grooves of the fetal kidney; viz., one transverse and one vertical groove. At this stage (8-9 weeks) there are already great differences as to size, capacity and form of the pelvis and its branches. The ureter may branch without the formation of a pelvis or one may find a well-differentiated pelvic dilatation at the site of the first division.

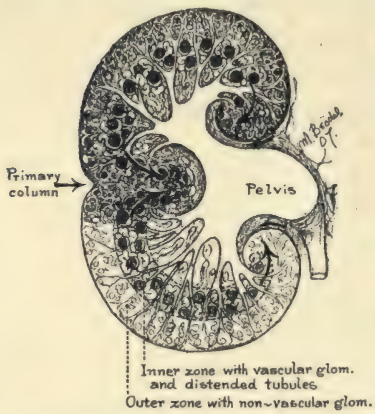


FIG. 77.—SCHEMATIC REPRESENTATION OF SUBDIVISION OF KIDNEY INTO LOBES, BY THE GROWTH OF THE CORTEX. Owing to the rapidly growing glomeruli and distended tubules of the inner zone the poles of the kidney fold inward, outlining the polar calices and in the center producing the primary transverse cortical column, which completes formation of calices.

As a consequence of the spreading of the inner layer of cortex the ureteral channels are beginning to undergo a certain characteristic change in direction. In their distal portion they are forced apart by the rapidly growing glomeruli and also by newly forming loops of Henle.

In their proximal portion the ureteral channels are brought into closer contact with one another by the dipping down and curving in of the cortex. As a result of these mechanical conditions the ureteral channels arrange themselves in fan-like groups (Fig. 75). This arrangement appears especially clear at the poles, and of these again the cranial, where the cortex is in a position to curve over a considerable distance. At this stage there is already an indistinct differentiation into cortical and medullary substance; i. e., the ureteral channels have increased in

number and appear closer together; there is also a slight dilatation of the first and second ureteral branches, which indicates the formation of the subsequent pelvis and calices. Especially the upper calyx appears well differentiated. In this way the position of the future papilla is marked. While the peripheral ureteral channels increase in number the central channels increase in caliber.

The Kidney at Later Stages of Its Development.—At the Age of 10

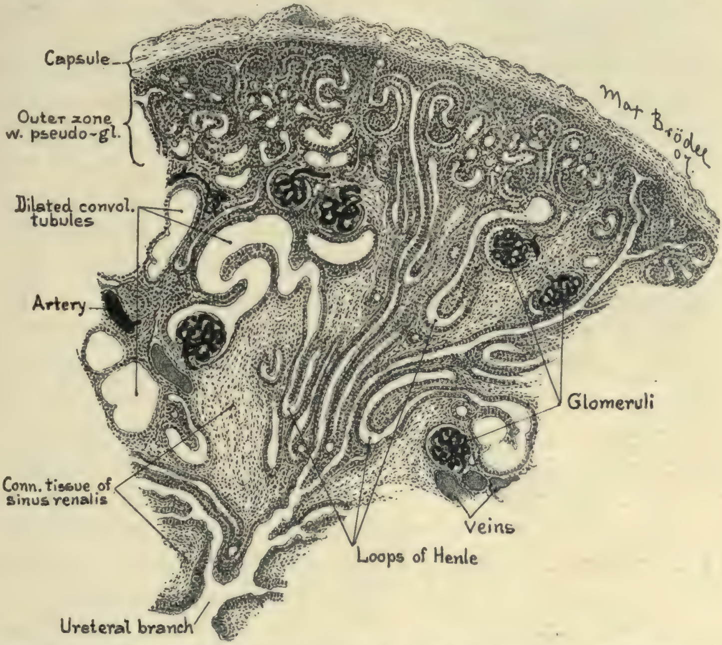


Fig. 78.—The Renal Parenchyma at the Age of Ten Weeks. Note the undeveloped peripheral glomeruli and the fully developed central glomeruli already vascularized. The distended convoluted tubules and loops of Henle belong to the inner glomeruli. As these develop, the connective tissue of the sinus renalis disappears.

weeks the lobes at the surface are still four or five; lobulation may, however, also be absent. The pelvis is not infrequently considerably expanded and is found surrounded by parenchyma on all sides. The kidney itself presents a thick round appearance. The primary transverse cortical column has attained much depth and as a consequence the pelvis appears divided into a cranial and caudal branch. The latter is, as a rule, the larger and has also the greater number of branches.

The ureteral branches or papillary ducts, as they might now be termed, show 3 to 4 successive dichotomous divisions. They are arranged in 4-5 fan-

like bunches, growing from the pelvic divisions, the lower division having three or two, the upper two. The cortex still consists of about three rows of glomeruli. The advancing columns of Bertin encroach upon the territory hitherto occupied by the connective tissue of the sinus renalis, which diminishes in extent as the cortex advances. At this stage there is a considerable advance of the tubular system noticeable. The straight tubules are quite numerous and begin to arrange themselves in bundles, the spaces between which are occupied by the central glomeruli and much dilated convoluted tubules (Fig. 78). The most striking feature of this stage, however, is the appearance of the loops of Henle, which are seen to dip down to various levels, those belonging to the older glomeruli extending into greater depth. The loop is often wide, in contrast to the sudden turn it has in the adult. Owing to this increase in the number of structures, the lumen of the ureteral channels or straight tubules is much lessened and it continues to decrease until it has reached the caliber of the ducts of Bellini in the fully developed kidney. This decrease is relative and in proportion to the size of the entire organ.

Eleventh Week.—As in the last described stage, the surface still appears divided into lobes, 4-5 being the usual number. These are caused by 1-2 transverse and 1 vertical groove or cortical column. The lobulation is quite marked and the columns reach down into the sinus renalis to considerable depth. On section these cortical columns are seen to consist of two central rows of pseudo-glomeruli with a thin connective tissue strand between them. The rest of the column consists of 1-2 layers of well-formed glomeruli (see Figs. 75 and 77). The primary column is generally a little above the middle of the kidney, the first secondary column somewhat below. The ureteral branches show an increase in the size of their lumen at the point of their third division, which marks the site of the future calices (Fig. 79). From these points on, the distal portions of the ureteral branches become much thinner owing to the lateral pressure caused by the rapidly developing structures composing the medullary substance. This increase in the lumen of the ureteral branches goes hand in hand with an evagination of a portion of the adjacent distal branches, which accounts for the great number of papillary ducts found in the adult at the region of the third division of ureteral branches.

At this age there are 4-5 rows of glomeruli, the central series being, as usual, the largest.

Twelfth Week.—Through new secondary columns of cortex the surface lobes have increased to 6-7, the first or primary column causing the deepest depression, the secondary being marked by shallower grooves. The primary columns on section are of dumb-bell shape, while the secondary columns are

simple wedges of cortex (Figs. 75 and 79). At the deepest portion of these cortical wedges the larger renal vessels are found. They have been carried into the depth by the growth of the column. The tubules (ureteral branches) are seen to bend toward these wedge-shaped cortical columns, so as to enter them at right angles or nearly so. Their direction is changed more by the primary than by the secondary columns (see Fig. 79).

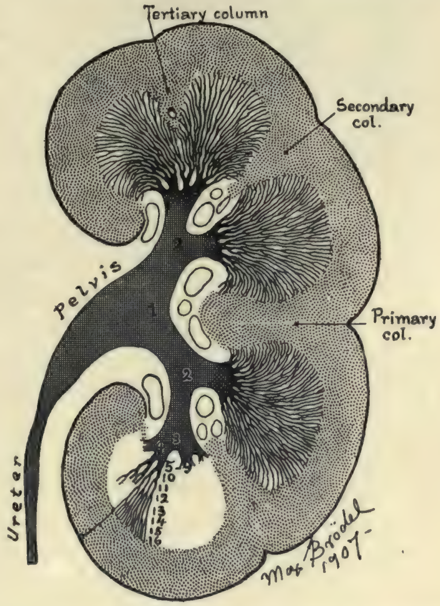


FIG. 79.—DIAGRAMS SHOWING THE URETERAL BRANCHES. The first division marking the pelvis, the second division the major calices, the third division the minor calices. All tubules from fourth to eighth divisions distend and ultimately form a single cavity from which all the ninth divisions take their origin. The further branchings occur inside the subsequent medullary substance.

The ureteral channels have increased and there are from 8-9 branchings, which would bring the number of end branches to about 300. As the division, however, is not always dichotomous, but may be into three or more branches, the number of end-channels may be greater. Figure 79 gives an approximate idea of the principle according to which the division of the ureter takes place. The first, second and third branchings take place inside the sinus renalis, the rest in the region of the subsequently forming medullary substance. Up to the region of the third branching the channels are of large caliber. This is the region of the future fornices. The divisions after this point follow in short intervals, the individual channels becoming much reduced in lumen. They remain narrow until the surface, where they slightly enlarge to form the ampullæ. (Fig. 78.)

There are now between four and five rows of glomeruli, the inner of which are best developed. The convoluted tubules in this inner layer are much distended as compared with the others. The character of the epithelial structures is about the same as in the adult. However, there is still an abundant mass of connective tissue between the tubules, as there is between all the individual structures of the kidney at an early stage.

FIG. 80.—SCHEMATIC REPRESENTATION OF INFLUENCE OF THE DOWN-GROWTH OF CORTEX ON THE URETERAL BRANCHES. The upper figure to the right shows the pelvic branches before the down-growth of the cortex has taken place. The figure to the left crudely represents the cortical columns. In the lower diagram this is inserted into the ureteral branches. Note how in this manner the original single pyramid has been divided into eight separate pyramids. The polar divisions are not complete.

THIRTEENTH WEEK.—The picture is much the same as in the last described stage. There are 6-8 lobes. The pelvis is quite large and may be either outside or inside the hilum, although we believe the latter to be the rule. The number of calices still corresponds to the number of lobes, but may be less, as there are quite a number of cortical columns, causing surface lobulation, which have not dipped down far enough to affect the shape and divisions of the pelvis. The fornices become now very much expanded and encroach distally upon three to four more branchings. The number of tubules at this junction of the ureteral tree appears, therefore, much greater than elsewhere. At the third division there are eight branches; i. e., the approximate number of calices, and, as this expansion or evagination includes the channels up to the eighth division after evagination, we count 256 channels opening into the calices, which represents about the usual number of papillary ducts; for we find in the adult the number of ducts on one single papilla varying between ten and thirty. A compound papilla may possess as many as 86. This process of evagination, however, is gradual and not complete before the 19th week. Papilla and papillary ducts as such cannot be distinguished very clearly as yet. Upward from the region of expansion there are 6-7 subsequent branchings of the ureteral channels. The cortical columns increase in depth and their advancing portion is now not pointed as it was in the earlier stages, but club-shaped. The hilum becomes narrower as the poles bend toward it. The secondary columns gain in depth and affect the form of the developing medullary substance to a large

extent, so much so that a whole pyramid may be divided by them. The loops of Henle invade the region of the branched ureter channels and advance for over one-half of the thickness of the entire parenchyma. The loops are still very wide and open. There are about five rows of glomeruli at that stage.

Fourteenth Week.—There are still 6-8 surface lobes and 4-5 calices with wide vault-like expansions, the fornices. Those at the poles are by far the largest. The papillæ become more plainly visible owing to a narrowing of the secretory channels from this region upward.

The columns of cortical substance appear exceedingly well developed and their position makes it quite certain that the form of the pelvis and calices depends upon their growth (see Figs. 80 and 81). The sinus renalis has diminished much in thickness and there is now little connective tissue between the pelvis and the ingrowing cortical columns.

The upper and lower calices display now a tendency to bend over toward the ureter, thus assuming a position which we often observe in the adult kidney. This condition has its cause in the growth of the cortex toward the hilum.

The division of the pyramids into secondary pyramids caused by cortical ingrowth continues to take place; at the same time new grooves make their appearance at the surface of the organ. There are now between 4 and 6 rows of glomeruli visible. The connective tissue between the individual structures of the kidney becomes more sparse as the tubules and glomeruli increase in number and size. The loops of Henle become larger, the lowermost reaching almost down to the papilla.

Owing to the growth of the glomeruli and the distention of the convoluted tubules, the straight tubules appear nearer to one another. If cut across they form groups of 3-5, which are the first indication of the subsequent medullary rays. These rays are seen clearest at the junction of cortex and medulla, while they lose in distinctness as they approach the surface.

Fifteenth and Sixteenth Week.—There are few changes as compared with the last described stage. The pelvis is still capacious and shows about 4-6 calices, whose fornices are quite large. The structures of the entire organ begin now to assume the form which we find in the adult kidney. The rest of the changes are only matters of degree, not of fundamental new formations.

Seventeenth to Eighteenth Week.—We have still 6-8 surface lobes corresponding to 5-6 calices. There is a great variation as to the form and capacity of the pelvis, which may be hanging outside the hilum or well walled off by the cortex of the poles. The pelvis may be very large, forming a single pocket, in cases where the cortex has not dipped down very far into the sinus renalis, or thin and branching, if the cortex has advanced considerably. The

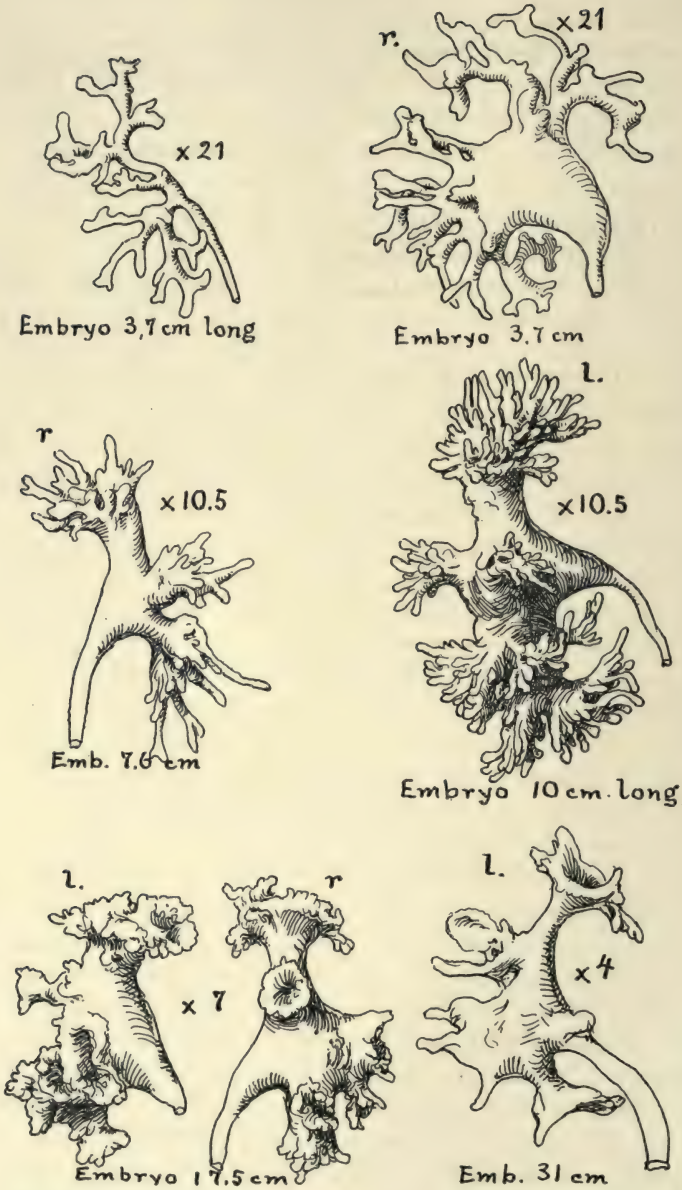


FIG. 81.—THE RENAL PELVIS IN THE EMBRYO. (After Hauch.)

upper pole seems, as a rule, more compact and larger than the lower pole, which is caused by a subdivision of the lower portion of the kidney into more pyramids by means of a greater number of cortical columns. The medullary substance increases perceptibly in thickness and the papillæ become longer and more clearly formed. The individual structures of cortex and medulla develop along the lines above described.

NINETEENTH WEEK.—The lobes have increased in number and there are now between 10-12. The number of cortical columns has likewise increased, and the secondary columns have attained considerable depth. The calices, however, remain 6-8, as the secondary columns do not all reach far enough inward to affect the shape or number of pelvic branches. The process of evagination of ureteral branches between the third and eighth division, which began during the 11th week, has now ceased. The peripheral glomeruli are still in state of formation and on section of the kidney the central portion of each cortical column shows one or two rows of non-vascular pseudo-glomeruli on either side of a thin connective tissue leaf.

TWENTIETH WEEK.—There are about 12-14 lobes and the pelvis as well as the sinus renalis has decreased in size owing to the pressure of the increasing parenchyma. The calices are narrow, but the fornices capacious. There are now 7-8 papillæ. The increase of the number of papillæ is caused by splitting of one pyramid from without in, produced by the downgrowth of an especially deep secondary cortical column. At the papillary end of the pyramid one sees, previous to complete division, a bridge of papillary substance containing tubules and vessels. This bridge connects the two halves of the dividing papilla for a short time, after which it gradually atrophies and the division becomes complete.

The pyramidal substance is now clearly differentiated; the loops of Henle reach far down and are very numerous. The lumen of the ureteral branches from the papillæ up is still comparatively wide. They are the subsequent ducts of Bellini, and their branching in the papilla takes place in rapid succession and short distances from one another. Medullary rays appear well marked, and their tubular constituents extend up to the surface. The medullary rays are arranged in regular intervals, the spaces between them being occupied by glomeruli and tubuli contorti. The glomeruli exist in 5-7 rows.

TWENTY-FOURTH TO TWENTY-FIFTH WEEK.—The surface lobes are 14-16 in number, as many as are found in the average kidney of the adult. The number of papillæ is nearly always somewhat less, i. e., 10-12. The fornices and calices remain 7-8. The reason for this disparity is the existence of a number of double or even triple papillæ in one common fornix.

The medullary rays are now very clearly demonstrable and the loops of Henle reach far into the neighborhood of the papillæ. The curve of the loop has now become sudden and sharp. There is still a considerable amount of connective tissue between the tubules. The glomeruli are arranged in rows of 7-8.

TWENTY-EIGHTH WEEK.—The general picture is much the same, 14 lobes, 10 papillæ, and 8 calices and fornices being the usual number. The glomeruli, however, have increased and number about 8-9 rows.

NEWBORN BABE.—The surface lobes number about 14, the columns of cortical substance producing this lobulation being 3-4 running in a horizontal, and one in a vertical direction. Besides these there are a few more irregularly arranged columns subdividing the larger lobes. These may reach as far down as the papillæ. These columns, having still pseudo-glomeruli in their central plane, extend far inward into the pelvic region. The new formation of glomeruli in the periphery has diminished some time before birth and there are now from 13-15 rows. The medullary rays are traceable up to the surface and their regular arrangement groups the glomeruli in well-defined columns. The subsequent growth of the glomeruli and tubules is slower in comparison with the intra-uterine development. Its effect is a gradual effacement of the grooves of lobulation. The lobulated fetal kidney in the majority of cases thus becomes again an organ with a comparatively smooth surface.

The size of the kidney in the different stages of its development is subject to individual fluctuation, and it is therefore possible to give only approximate measurements. The transverse diameters are as follows:

Embryo of 3 weeks	0.2 mm.
" " 4 "	0.4
" " 5 "	0.5
" " 6 "	0.8
" " 8 "	1.5
" " 10 "	3.5
" " 12 "	4.0
Fetus " 20 "	9.0
Newborn	25.0
Adult	50.0

If we briefly RECAPITULATE the morphological side of this development, we must emphasize:

First and second month, branching of ureter in sinus renalis without appreciable expansion of organ (Fig. 75).

Ninth and tenth week, dilatation of ureter at points of first, second and third division. Later, narrowing down of lumen of peripheral branches.

Formation of columns of cortex: primary, deep and dumb-bell shaped; secondary, shallow and wedge-shaped; tertiary, quite shallow.

Only primary columns affect the form of the pelvis and that of the surface, as they develop earliest and extend deepest. These columns divide the ureteral branches into groups, which mark the beginning of the pyramids. The longitudinal primary column reaches from the lateral surface of the upper to that of the lower pole, without dividing the corresponding pelvic branches of the poles. This is because these calices bend away from the cortical columns toward the hilum. However, the lateral pelvic branches are divided by this column into a ventral and dorsal group (Fig. 75).

The transverse columns are deepest in the center and of these the first primary column just above the middle of the kidney is the oldest and deepest and it is the cause of the frequent narrowness of the upper major calyx in adult kidneys. The cortex from the upper pole bends toward the hilum and compresses the calyx at the mesial side.

The narrowness of the minor calices is likewise caused mainly by the pressure of the cortex acting upon the branches of the pelvis.

Some pelves remain distended, others contract. The latter have few but complex papillæ, which are separated by deep columns of Bertin. While the number and position of the lobes correspond in the earlier stages more or less to that of the papillæ, in the later stages of development there is a marked increase in the number of the lobes without any increase in the number of calices.

II. THE POST-FETAL GROWTH OF THE KIDNEY.

After birth of the child the growth of the kidney is characterized by a further development of the elements already extant, both in number and size.

The cortex increases in thickness and causes the surface lobes to become less distinct or to disappear. After sixteen months they begin to smooth out and at the age of four years the surface has attained the character it maintains during life. The medullary substance grows much less in proportion than the cortex. The length of the pyramids in relation to the length of the kidney is $\frac{1}{4}$ to $\frac{1}{6}$ in newborn and children, while in the adult it is $\frac{1}{8}$ to $\frac{1}{12}$.

The Pelvis.—The main character of the pelvis, i. e., its divisions, remains the same; but the shape of the individual parts of the pelvis is subject to considerable changes.

While in the later fetal stages and in the newborn the poles bend toward the hilum, causing the upper and lower calices to do likewise and compressing the pelvis at its exit, the adult kidney has straighter upper and lower calices and its pelvis is more capacious and situated more outside the parenchymal border at the hilum. The pelvis of the newborn is more included within the

sinus renalis; the calices are bent more toward the hilum and they are narrower than those of the adult (Fig. 86).

Calices.—As to the calices themselves, their form remains approximately the same, also their number, which varies in different kidneys from 3 to 12, the average number being 7.

There is always an upper and lower and two longitudinal rows of 2-4 each.

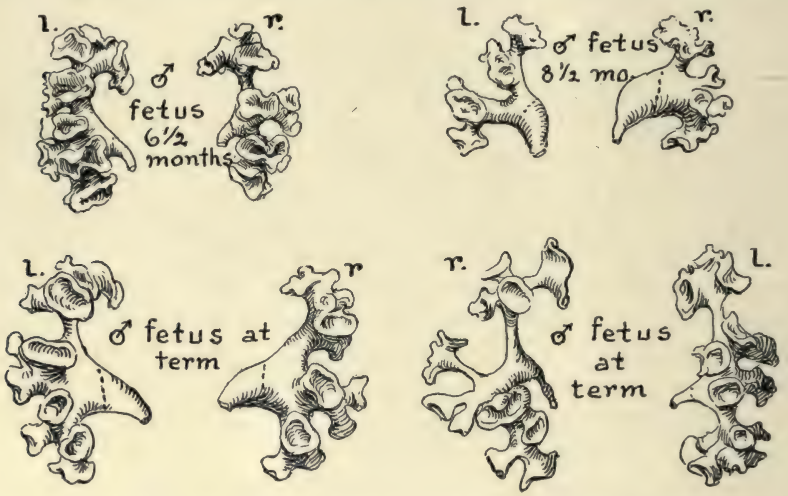


Fig. 82.—The Renal Pelvis in the Fetus. (After Hauch.)

There may, however, be four longitudinal rows. This condition is associated with three longitudinal cortical columns instead of one.

Occasionally one meets with a so-called emigrant calyx, which may come off at the pelvis near the hilum. It seems, however, probable that pelvic diverticuli have been described as emigrant calices.

The lumen of the calices varies from 1-4 mm. or more, and their length from 2 mm. to 2 cm.

Fornices.—The fornices or vault-like expansions at the distal end of the calices vary in number from 4-16, and their form is very varying. During the later months of intra-uterine life and in the newborn they are relatively capacious, having broad leaf-like collars which fold over toward the pelvis and hilum. If the papillæ are compound these delicate fornices show very complicated forms (see Fig. 82). The pelvis, with its short minor calices and broad leaf-like fornices, at this stage greatly resembles the pelvis as seen in some of the mammals; sheep, antelope, pig, hare, dog, etc. In corrosion speci-

mens of human kidneys of that age the vessels are seen as in those animals partially enveloped by these broad leaf-like expansions of the fornices. They begin to develop between the fourth and fifth months of fetal life, and are most marked during the later months up to term, and begin to grow less distinct during the first and second months after birth.

Relation of the Pelvis to the Surface of the Kidney.—During the latter months of intra-uterine life and at term the surfaces of the kidneys show little

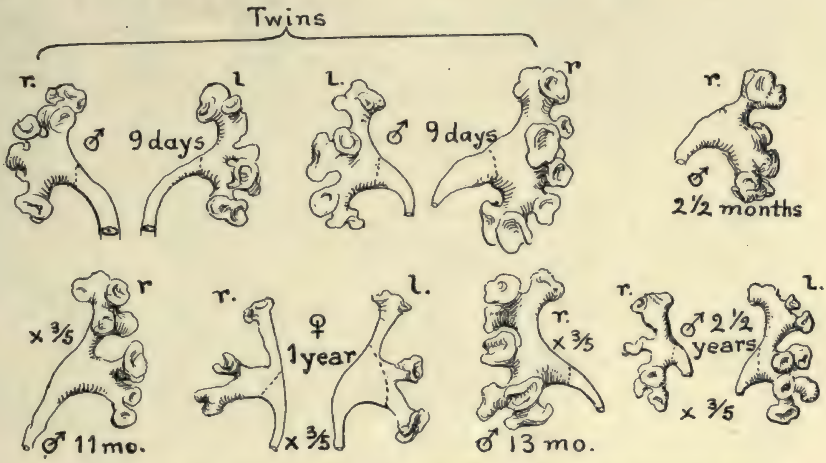


Fig. 83.—The Renal Pelvis in Infants. Upper row natural size; lower row × $^3/_5$. (After Hauch.)

variety in form. The kidney is short, broad and thick, its length being only 1½ to 2 times its breadth. It appears as though it were compressed from above down, whereby the hilum becomes narrowed to a slit, directed either oblique, vertical, or transverse. Its usual situation is dorsal, owing to the rotation of the kidney around its long axis, occurring between the sixth and ninth weeks of the embryonic stage. It has been shown that this rotation is the cause of the preponderance of the anterior vascular system and the posterior position of the pelvis.

There is marked lobulation, the lobes varying from 8 to 26, the most frequent number being 12 to 14. However, on the surface of quite a number of kidneys at term there is hardly any division into lobes visible. In spite of the smooth surface, however, there may be very deep cortical columns and as a consequence marked branching of the pelvis, narrow calices, etc.

On examination of the surfaces of many kidneys followed by studies of

their pelves, it becomes evident that there is no definite reliable relationship to be made out between the two. We find many branched, as well as many simple, pelves associated with both smooth and lobulated kidneys. Likewise, there is

Fig. 84.—The Renal Pelvis in the Adult, × ½. Under each figure are given sex and age of individual. (After Hauch.)

no certain connection between age and surface lobulation, for we often observe strongly lobulated kidneys in old individuals and smooth kidneys in infants. However, one fact deserves to be mentioned; i. e., that abnormal blood supply is in the majority of cases associated with abnormal divisions of the ureteral tree or abnormal position of the pelvis. The position and division of the ureter are established before any vessels invade the kidney and, if there be any ir-

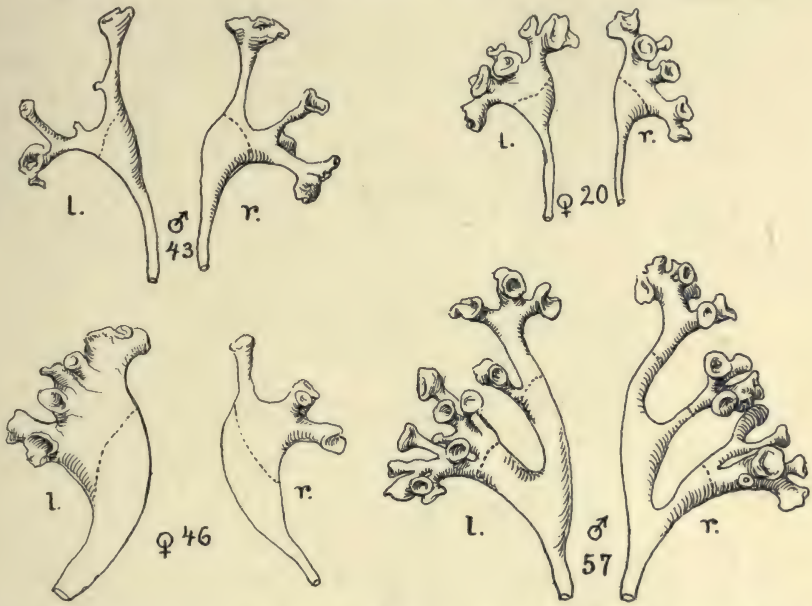


Fig. 85.—Similarity of Form of Pelvis on Two Sides. (After Hauch.)

regularity in these directions, the vessels adjust themselves to them and we find:

I. If the pelvis is on the anterior region of the hilum, the majority of vessels enter above and behind the pelvis.

II. If the pelvic divisions are of very complex character, so as to show separate branches entering the hilum, several arteries arise at separate points from the aorta.

III. In case of double ureter there is also more than one separate artery entering the parenchyma.

We have, then, secretory as well as circulatory, several separate kidneys, one on top of the other. Their only vascular communications are the venous anastomoses around the ureteral branches at the base of the pyramids, and on the surface.

The fornices do not correspond to the lobes on the surface, as there may be very extensive lobulation in kidneys possessing only a few fornices, as well as the opposite condition. The pyramids and papillæ, however, correspond exactly to the lobulation. If there be but few fornices in a kidney they are seen to contain usually compound papillæ. As to the number of the fornices and calices in the different ages and sexes, Hauch gives us interesting data, an abridgment of which follows:

Average Number of Fornices Counted in 145 Cases

		In the Male			In the Female		
		R. K.	L. K.	Together	R. K.	L. K.	Together
Fetus and Newborn	34	8.3	8.3	8.3	5.3	7	6.2
Children	32	7.8	8.2	7.9	7.5	7.4	7.4
Adults	79	8.9	7.8	8.2	7.3	6.9	7.1
Total	145	8.3	8	8.2	7.2	7	7.1

Average Number of Calices Counted in 113 Cases

		In the Male			In the Female		
		R. K.	L. K.	Together	R. K.	L. K.	Together
Fetus and Newborn	21	7.4	6.7	7.1	4	7	6
Children	22	5.2	5.6	5.4	5.3	6.5	5.6
Adults	70	6.4	6.4	6.3	5	5.6	5.3
Total	113	6.3	6.4	6.3	5	5.8	5.4

These tables show that, while age makes no difference in the number of calices and fornices, there is a slight difference in their number in the sexes, the male having generally more calices than the female. As to the general character of the surface, there is no important difference between the right and left kidneys and also no difference between the male and female; that is to say, there are just as great or greater variations between kidneys of the same sex and the same age.

Size and Shape of the Kidneys.—The kidneys in the newborn are about three times as large in proportion to the body weight as in the adult. While the weight of the kidneys as compared with that of the body is given as 1:80 in the infant, it is 1:280 in the adult. Other writers give the following numbers:

Meckel,	Infant	1:50
	Adult	1:290
Huschke,	Infant	1:82
	Adult	1:225

The actual length of the kidney in the first two years, as given by Helm, is stated in the following table, which demonstrates the fact that the kidney increases to double its length during the first two and a half years of life.

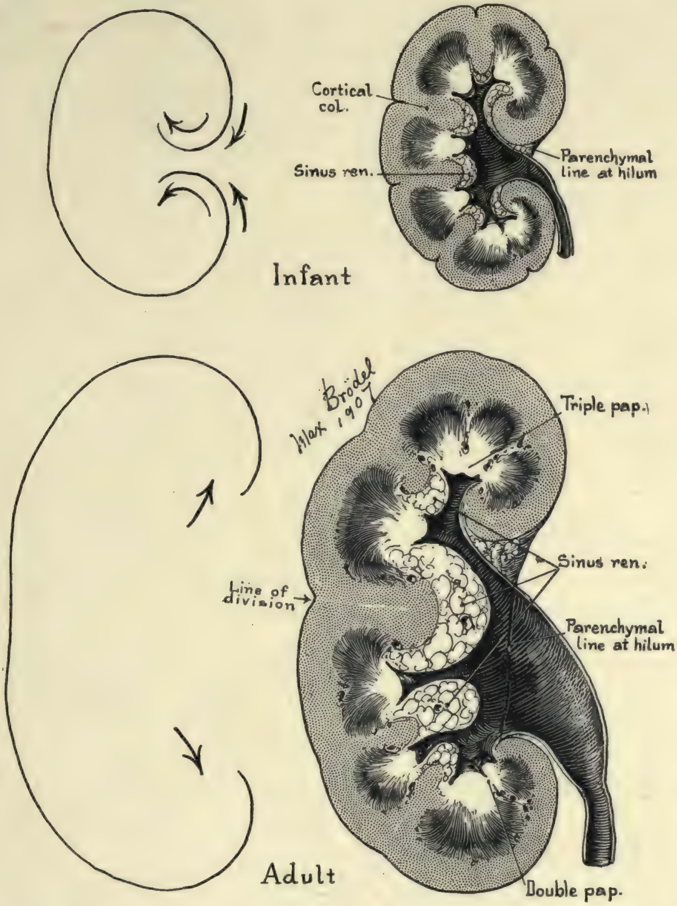


Fig. 86.—The Opening Out of the Kidney and Its Influence on the Topographical Anatomy. In the infant the kidney resembles a bud, in the adult an open flower.

The sinus renalis is much smaller in the infant than in the adult, a condition caused by the close proximity of the cortical columns to the pelvis in children. In the adult the pelvis changes its position and drops more outside the kidney, leaving more room for the sinus to develop (Fig. 86). Fat accumulates

in it and it is often seen to assume large proportions. The columns of Bertin then appear farther away from the pelvis.

		Right Kidney	Left Kidney
Children of	⅛ year	4 cm. 3.7 "	4.5 cm. 4.2 "
" "	½ "	4.5 "	5 "
" "	1 "	5.75 " 5.5 " 6 "	6 " 5 " 6.5 "
" "	1½ years	6 "	6 "
" "	1¾ "	7 " 7 "	7 " 7.5 "
" "	2½ "	7.5 "	7.5 "

The entire form of the kidney undergoes a radical change, which may be compared with the opening up of the bud into a flower.

The parenchyma of the poles in the newborn and infant closes tightly down upon the pelvis at the hilum, while it appears unrolled or straightened out in the adult. The hilum is then wide open and the pelvis freely palpable (Fig. 86).

The papillæ in the infantile kidney are pointed and long. Through continuous new formation of loops of Henle, however, the pyramids grow in width and as they invade the papillary portion they produce a flattening and shortening of the papillæ in the adult.

The relation in the thickness of cortex and medulla in the different ages is of considerable interest, and Toldt found that the cortex is thinnest in relation to medulla in the newborn. A few of his measurements of cortex and pyramid through the axis were:

	Cortex	Medulla	Relation, About
Embryo, 3 Weeks	0.82 mm.	1.54 mm.	1 : 2
Newborn	1.80 "	8.31 "	1 : 4
Adult	9 "	16 "	1 : 2

Hauch gives elaborate tables, obtained by extensive measurements. He took the large vessels at the base of the pyramids as dividing line and measured through the axis of the pyramid. These measurements were taken at different places of the same kidney, and in the table he gives the average measurement obtained in this manner.

This table shows that there is a steady increase of the thickness of the cortex as compared with the thickness of the medulla. Still, there is a marked irregularity, not only between the measurements in kidneys of the same age, same sex, or the two kidneys of the same individual, but even in different places of the same kidney.

The increase in thickness of the cortex is due to a growth of the already existing structures, as well as to a new formation of similar structures. Up to the age of about four years the glomeruli increase in number, while later on

Age	Pyramid	Cortex	Relation in %
Fetus 6 months	5.60 mm.	1.50 mm.	100 : 26.3
" 6 "	5.50 "	1.50 "	100 : 27.2
" 6 "	4 "	1.50 "	100 : 37.0
" 7 "	4.50 "	1.50 "	100 : 33.3
" 7½ "	5.83 "	1.67 "	100 : 22.2
" 7½ "	7 "	2 "	100 : 22.2
" 8½ "	8.75 "	2.25 "	100 : 25.7
" 8½ "	8.50 "	1.50 "	100 : 17.5
Newborn	8.16 "	3 "	100 : 24.9
"	8.16 "	1.83 "	100 : 22.9
"	8.33 "	2.33 "	100 : 28
"	6.38 "	2 "	100 : 31.2
Child 9 days R. K.	6 "	1.50 "	100 : 21.4
L. K.	6.67 "	1.83 "	100 : 27.5
" 9 " R K.	5.50 "	1.50 "	100 : 27.5
L. K.	5 "	1.50 "	100 : 30
" 4 " R. K.	4.75 "	1.75 "	100 : 36.8
L. K.	4.25 "	1.75 "	100 : 41.1
" 6 " R. K.	7.67 "	2 "	100 : 26.5
L. K.	9.33 "	2 "	100 : 21.4
Child 13 months	7.33 "	4.73 "	100 : 40.9
" 16 "	7.88 "	3.75 "	100 : 63.6
" 7 years R. K.	7.33 "	3 "	100 : 40.9
L. K.	6.25 "	2.25 "	100 : 36
" 8 " R. K.	10.40 "	6.60 "	100 : 57.9
" L. K.	9.73 "	6 "	100 : 62.1
Adult "	8 "	5 "	100 : 62.1
" "	15 "	6 "	100 : 40
" "	17.33 "	10 "	100 : 57.6
" "	14.75 "	10.75 "	100 : 72.5
" "	13.25 "	10.25 "	100 : 77.4
" "	11.60 "	8.80 "	100 : 75.9
" 36 years	13.40 "	4 "	100 : 44.7
" 83 " R. K.	9.33 "	4.33 "	100 : 46.4
L. K.	13.25 "	6.50 "	100 : 60.4

they move further apart from one another, increasing at the same time in size. The space between them becomes occupied by the tubuli contorti.

While the medullary rays in the fetus and newborn reach up to the surface, in the adult they do not, but are separated from it by the zone of convoluted tubules developing just beneath the capsule. The medullary rays do not extend to the central plane of the cortical columns, but cease a varying

distance from it. If the cortical column has no surface groove the cortex has grown until the triangular area is filled and the depression has been caused to disappear. This growth consists mainly of convoluted tubules.

Hauch and others mention the existence of so-called papillary bridges and ridges, which have been observed with some regularity in older fetuses and young children. They make their appearance in the sixth month of fetal life and disappear after the 3-4th year. These bridges and ridges seem more numerous in kidneys having many lobules.

Bridges are delicate strings of mucous membrane, with or without secretory structures in their interior. They pass from one papilla to another, or from the side of a fornix over to the papilla.

Ridges are folds of mucous membrane containing more or less of kidney structures, running along the walls of the pelvis or passing from one papilla to another, or also from the fornix wall to a papilla.

While some authors, as Key, think these formations mark the beginning of a junction of two papillæ, Toldt believes they represent the last stage of the process of splitting of a papilla. Hauch advances the following opinion: (1) The papillæ grow into the pelvis and in doing so lift up bridges of mucous membrane. As the papilla pushes further in, these bridges atrophy and finally disappear; (2) the columns of Bertin force their way into the pelvic region and protrude between the pyramids, dividing the papillæ and coming to the pelvic surface as a ridge.

CHAPTER IV.

THE ANATOMY OF THE KIDNEY AND URETER

ANATOMY OF THE KIDNEY.

FORM AND AXIS.

The form of the kidney after removal from the body differs considerably from the functioning organ *in situ.* The escape of blood and urine renders the parenchyma and renal pelvis flaccid and makes it difficult to note the real form and size of the kidney, its axis and relationship to neighboring structures. It is therefore necessary to study the form of the kidney before its removal, and with its vessels and pelvis in a normal state of distention or filled with some suitable injection mass, which will preserve the exact form after removal.

The usual text-book description suffices as an introduction, viz.: The kidney is a bean-shaped organ with an upper and lower pole, a lateral convex margin, and a median concave margin, in the middle portion of which is found a deep pocket, the sinus renalis. The anterior surface of the kidney is more bulging than the posterior. Through the hilum the vessels, nerves, and ureter enter and leave the sinus renalis; the sinus contains also a varying amount of fat.

It may be added that the anterior surface faces forward and outward, the posterior surface backward and inward. The transverse axis consequently is directed obliquely backward at an approximate angle of 40 degrees with the antero-posterior axis of the body. The upper poles of both kidneys are about 5 cm. apart from one another, the lower 7-8 cm. Thus, the hilum *in situ* is directed not mesially, but obliquely, anterior and inferior. Also note well that:

1. The upper pole leans slightly forward, following the curve of the diaphragm. On account of its higher location this is more marked in the left kidney than in the case of the right.

2. On the other hand, it is claimed that the upper pole is pressed backward on the right by the liver, on the left by the fundus of the stomach.

Doubtless both conditions may occur, although the first-named is by far the more frequent.

3. The lower pole is pushed slightly backward by the colon ascendens on the right and coils of small intestine on the left.

4. Again, it is claimed that just the opposite takes place, viz.: that the M. quadratus lumborum crowds the lower pole slightly forward.

It follows that the side view of the long axis of the kidney is seldom found straight, but presents an S-shaped curve, in case conditions (1) and (3) prevail; or a reversed S, in case of (2) and (4); or, again, the axis may be a concave line if conditions (1) and (4) are combined; or convex, if forces (2) and (3) are at work.

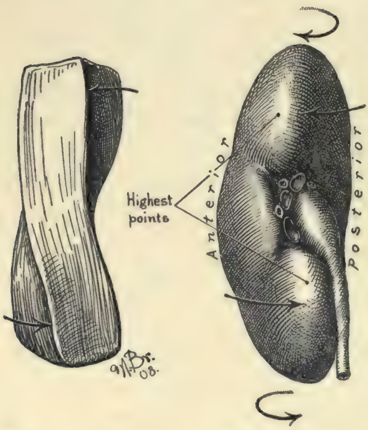


FIG. 87.—DIAGRAM OF LEFT KIDNEY, SHOWING TORSION; THE UPPER POLE TWISTED IN AN ANTERIOR DIRECTION; THE LOWER, IN THE OPPOSITE. The figure to the left shows similar torsion on a flat piece of rubber.

In addition there exists a slight spiral torsion, especially noticeable at the median portion of the poles (Fig. 87). The median portion of the upper pole is rotated anteriorly while the median portion of the lower pole is turned posteriorly. This spiral turn accounts for the oblique direction of the hilum and the decidedly posterior position of the renal pelvis and ureter. Its cause is found in the mechanical influences of the neighboring structures in early fetal life, viz.: the median portion of the upper pole is pressed by the large adrenal body against the crus of the diaphragm, causing it to turn forward, while the median portion of the lower pole is pressed backward by ventro-lateral pressure, exercised by the large sexual gland (Fig. 68).

The ventral surface is more prominent than the dorsal, which likewise has its cause in the above-described mechanical influences during fetal life, viz.: the entire kidney, except the lower two-thirds of the anterior face, is hemmed in by neighboring structures, such as the posterior abdominal wall, the adrenals, and the sexual gland. The growth of the parenchyma, therefore, is more vigorous in the direction of least resistance, which is in the middle or lower third of the anterior portion, and as a consequence this is the most prominent portion in the kidney of the adult.

The upper pole of the kidney is usually broader, its contour forming a semicircle, while the lower pole appears more narrow and pointed. This pe-

culiarity is probably caused by the pear-shaped form of the posterior abdominal niche in which the kidney grows to its ultimate size. The lateral abdominal wall and psoas muscle cause the lower apex of the niche to become narrower and the lower pole of the kidney gradually assumes the shape of a section of this cone.

After a careful and exhaustive study of the kidneys of many embryos and of more than 100 normal human kidneys, one-half of which were converted into corrosion preparations, it became evident the most potent factors in the determination of the form of the kidney were: (1) the form and location of the region of the first ureteral division, whether outside or inside the kidney; and (2)—the more important of the two—the degree of rotation the kidney underwent before its vascularization became established.

I. Form and Location of the Region of the First Ureteral Division and Its Influence upon the Form of the Kidney.—The bean shape, which in its true character is preserved in only a small percentage of cases (Fig. 92), is the result of the rapid parenchymal growth in the periphery of the kidney during the embryonic stages. This growth causes the poles, as well as the anterior and posterior lips, to re-curve toward the hilum. Radiating from the hilum are notches, two on the anterior and from one to two on the posterior surface. These notches become shallow as they proceed and are generally lost in the middle of the anterior or posterior surface. Their cause is also found in the above-described re-curving of the growing parenchyma toward the hilum.

At the hilum these notches are found 1½ to 6 cm. apart, according to the shape of the pelvis, the arrangement of the major calices and of the vascularization. If the region of the first ureteral division (pelvis) is inside the kidney the hilum is short, the notches and poles close together. Such a kidney may be compared with a closed flower bud. It is round, short, and thick. If, on the other hand, the pelvis be far outside the hilum, and the major calices enter the hilum separately and some distance apart, the hilum is long drawn out, the poles and parenchymal lips are far apart, likewise the notches. This form of kidney may be compared with an open flower. It is long, narrow, and thin. The anterior notches are seen in types *d, e,* and *g,* a solitary posterior notch in *i.* The lower anterior notch may diminish in size or disappear altogether in cases of torsion of the lower half of the kidney, such as seen in types *f* and *h.* (See Figs. 91-95.)

Fetal Lobulation.—The same factor which causes the poles to re-curve toward the hilum, viz.: the preponderating growth of the peripheral portions of the parenchyma, also brings about the fetal lobulation, and it appears that the lesser or greater degree of lobulation during the embryonic stage determines

whether the subsequent postfetal cortical growth up to the fourth year will suffice to eliminate the marks of lobulation on the surface. It is also possible, however, that the degree of postfetal cortical growth is variable, and that perhaps the persistence of lobulation is traceable to a pathological process during the early years of life, which interferes with the complete development of the peripheral layer of the tubular system. The lobulation of a kidney would, therefore, signify a condition of diminished resistance in case of a subsequent disease. This theory seems to be supported by the well-known fact that many diseased kidneys show marked lobulation. Of course, the disease often emphasizes the phenomena, but the original extent of lobulation is generally noticeable on the normal or less affected portions. The number and distinctness of lobulations vary; there may be from 7 to 26, either sharply marked or incomplete and less distinct lobulations.

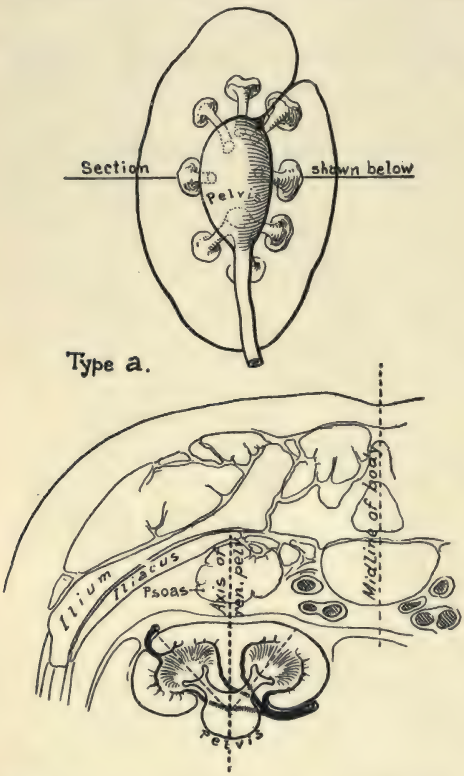


FIG. 88.—DIAGRAMS OF ECTOPIC KIDNEY, SHOWING ANTERIOR PELVIS AND CALICES POINTING OBLIQUELY BACKWARD. Note abnormal distribution of blood-vessels; supernumerary branches entering the kidney in various ways. The contour of the kidney is elliptic.

II. Influence of Rotation upon the Form of the Kidney.—Both the closed and the open bean shape are subject to still further changes, which in their extremes render the original form almost unrecognizable.

The rotation of the kidney during its ascent changes the position of the renal pelvis from an anterior through a mesial to a mesio-posterior position, and it is mainly the degree of this rotation made permanent through the vascularization at the eighth week of embryonic life which determines (1) the location of the hilum, (2) the axis of the renal pelvis, (3) the direction of the anterior as well as the posterior row of calices, (4) the contour of the kidney,

(5) the area of greatest activity in parenchymal development, (6) the distribution of the vascularization and location of the plane of arterial division.

In Figures 88-95 is shown a complete series of kidneys representing the various forms, all of which were determined by the above-mentioned factor, viz., rotation.

When attempting to classify them it was soon apparent that we had to deal not with definite well-pronounced types, but with an even chain of transition forms beginning with the most extreme form of non-rotation (Fig. 88), and ending with the most pronounced form of rotation (Fig. 95).

The various intermediary forms between these extremes are not types, but were picked out of a continuous chain of gradual changes, for the reason that they combined all the essential features of the groups they represent. It must be understood that within the confines of each group there are numerous variations, leaning either toward the preceding or the following groups; or also there may be odd and strange features, such as four, five, or six extrarenal major calices, double ureters, supernumerary vessels, etc.; but in the main the types *a-i* cover all possible topographical features of the kidney, excepting only pronounced malformations, such as described in Chapter XXVIII.

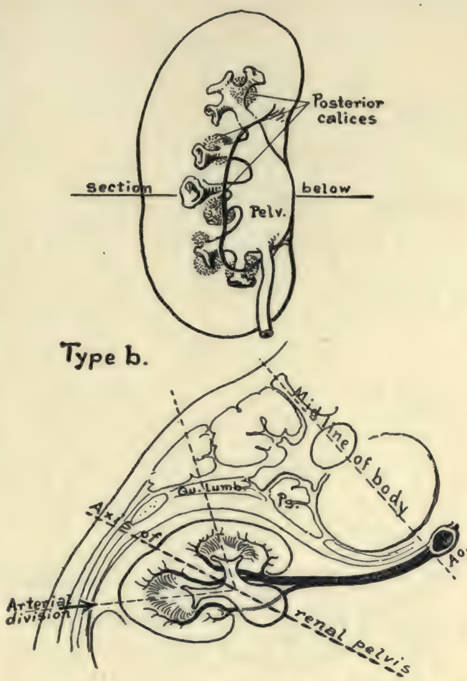


FIG. 89.—DIAGRAMS SHOWING KIDNEY IN NORMAL POSITION BUT INSUFFICIENTLY ROTATED. Pelvis in ventro-mesial position, anterior row calices points lateralward, posterior row points backward. The posterior arterial system is larger than the anterior.

The greatest number of kidneys are formed similar to types *e, f, g, h,* and *i, g* having the greatest number of representatives, and, if a type form has to be decided upon, this would be the one selected. Groups *a-f* would then have to be designated as kidneys with insufficient rotation, *h* and *i* kidneys with excessive rotation.

(1) Effect on the Location of the Hilum.—The various degrees of rotation affect the location of the hilum in so far as in *a* it is found in front; in *b, c,* and *d,* leaning more and more toward the vertebral column; in *e* it is situated just in the middle plane of the kidney; in *f,* torsion of the lower pole gives the hilum an oblique posterior direction (see Fig. 87); in *g* the hilum is found in a mesio-posterior position, a form which, in *h,* through torsion of the lower pole, becomes still more emphasized; *i* shows finally the hilum shifted to the posterior surface of the kidney.

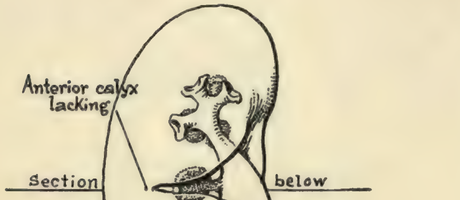


Fig. 90.—Ventro-mesial Position of Pelvis: Deep Transverse Groove on Anterior Surface Associated with Absence of Middle Anterior Calyx. Above and below calices point as in preceding figure. Circulation the same as in Figure 89.

(2 and 3) Effect on the Axis of the Renal Pelvis and the Direction of the Two Rows of Calices.—In *a* the axis of the pelvis runs in an antero-posterior direction, with the two rows of calices pointing obliquely backward to the right and to the left. In *b, c,* and *d* the axis of the pelvis, as shown by the heavy dotted line, gradually assumes a more transverse position, which in *e* coincides with the topographical axis of the kidney. The directions of the two rows of calices change in a similar manner, the anterior row in *b* and *d* pointing laterally, while the posterior row points backward. In *e* both rows of calices are symmetrical and run obliquely in an interior and posterior direction. Owing to a deep transverse notch at the anterior margin of the hilum in *c,* the middle anterior pyramid and calyx are absent. To be more correct, however, and to distinguish between cause and effect, it should be said that, owing to the failure of the middle anterior calyx to develop, the parenchyma curved in at the corresponding region and formed the deep furrow.

In *g, h,* and *i* the pelvic axis shifts still further, its direction finally becom-

ing obliquely anterior. The two rows of calices then assume the characteristic distribution so often seen in kidneys, viz., the posterior row points laterally while the anterior points straight forward in the bulging anterior portions of the parenchyma. In *i* the posterior middle calyx is lacking, and as a consequence one finds a deep transverse parenchymal notch in the posterior surface of the kidney. This form is the reverse of *c*, *g* the reverse of *d*, *h* the reverse of *b*.

(4 and 5) Effect on the Contour and Form of the Kidney.—In *a* the outline is oval with the exception of one or several furrows for the reception of vessels. The organ is flat and bears on its dorsal surface the impression of the structures to which it became permanently attached, viz., sacrum, iliac vessels, psoas or vertebra, as the case may be. The greatest activity in parenchymal development takes place in the direction of least resistance—i. e., above and below and to right and left.

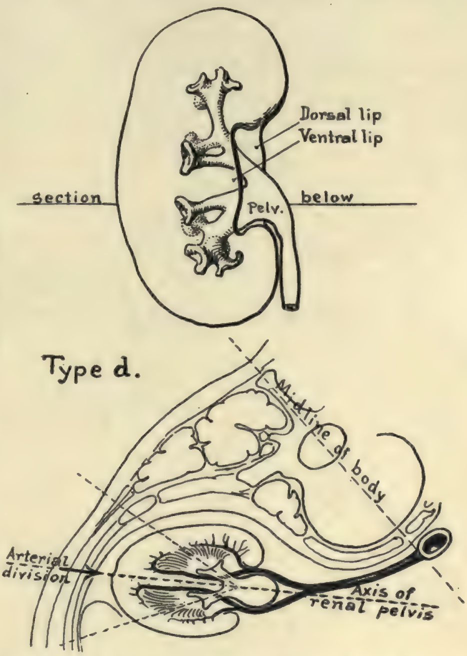


Fig. 91.—Mesial Position of the Pelvis; Dorsal Lip of Hilum Still More Prominent Than Ventral. Calices pointing approximately as in Figure 89. The anterior and posterior circulations are of equal size.

From *b* to *d* the contour gradually changes into the shape of a bean, the posterior parenchymal lip of the hilum forming the mesial outline. The parenchyma develops chiefly in a posterior and lateral direction as well as above and below.

In *e* we have the ideal bean shape; in *f*, a distorted variation caused by backward spiral torsion of the mesial portion of the lower pole. The parenchyma displays its greatest activity in a lateral direction. From *g* to *i* the bean shape becomes gradually lost, and in the most pronounced types of group (*i*) the contour of the kidney approaches again the oval form of group (*a*). The parenchyma develops most in or just below the middle of the anterior portion.

(6) Effect on the Distribution of Vascularization.—Since the per-

manent vascularization of the kidney is not established until the rotation has been nearly completed, the degree of rotation must necessarily greatly affect the topography of the vessels. The establishment of the permanent arteries appears to take place without regard to the anatomical axis of the kidney. The vessels run from the aorta straight to the nearest portion of the hilum, or, if that be turned away from the aorta, they either curve around the lateral border until they reach the hilum or plunge into the nearest portion of the parenchyma.

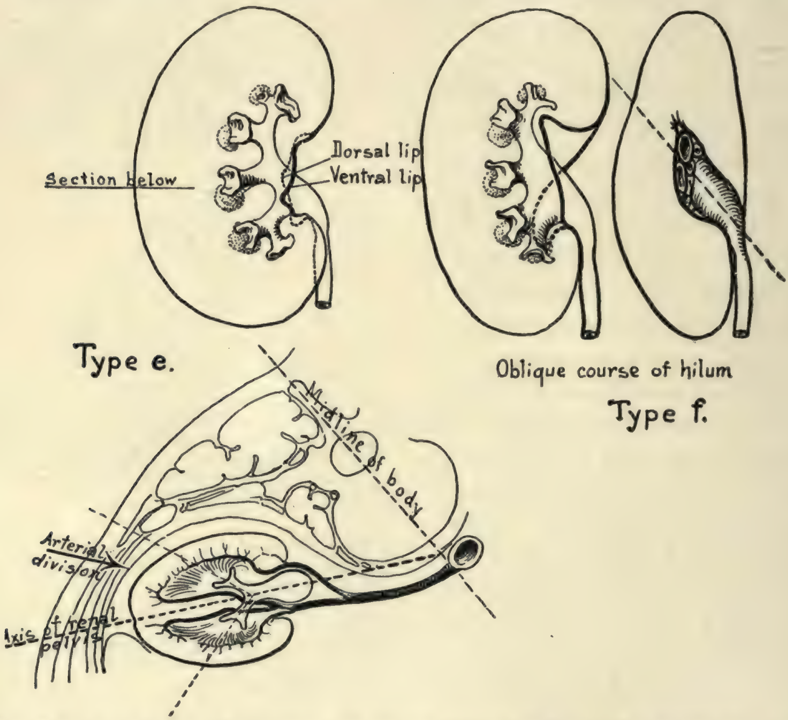


Fig. 92.—Pelvis in Mesial Position; Lips of the Hilum of Equal Prominence. Anterior calices point obliquely forward, posterior obliquely backward. In right-hand figure the greater twisting of the kidney modifies the contour of hilum. The anterior arterial system is larger than the posterior. Type *e* represents the ideal bean shape and is the only kind of kidney that does.

When the pelvis with its branches is reached, they divide and continue in two systems on either side until they approach each other again on the other surface of the kidney. The plane separating the terminal vessels of these two systems is the line of natural division of the arterial circulation, so important to the surgeon. Its location on the surface, as will be shown, is dependent on the

degree of rotation the kidney had undergone when the permanent circulation became established. The location of the plane of division is indicated by arrows (see Figs. 89-94).

In *a* the rotation has failed to take place, the hilum having remained on the anterior surface of the kidney, and the vessels curve around the border of the organ before they plunge into the parenchyma, or they dip directly into the cortex of the posterior surface or lateral border. Since the ectopic kidneys generally have several vascular pedicles whose arteries traverse the kidney in many directions, it is impossible to speak of a definite plane of arterial division.

In *b* and *c* the rotation of the kidney has placed the posterior portion of the hilum in the best available position for the entrance of the blood vessels, and as a consequence we find the majority of arteries coursing behind the pelvis, while only small branches are found in front. The least vascular plane coincides with the plane of the anterior row of calices.

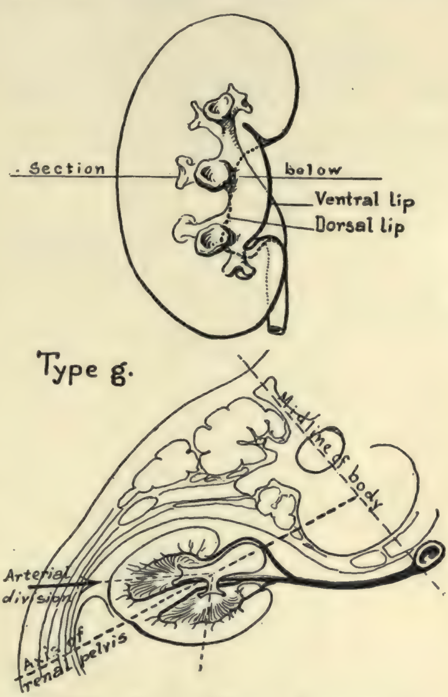


FIG. 93.—PELVIS IN DORSAL POSITION; POSTERIOR LIP OF HILUM SHORTER THAN ANTERIOR. Anterior calices point forward; posterior lateralward. Anterior arterial distribution much greater than posterior. More kidneys conform to this type than any other.

In *d* the rotation has placed the hilum directly in the middle of the path of the arterial supply, and the division of the vessels is such that approximately the same number of arteries run in front of the pelvis as behind. The least vascular plane of such kidneys is usually found in the center of the organ, coinciding with the longitudinal cortical column.

In *e, f, g, h,* and *i* the rotation of the kidney places the anterior portion of the hilum in a more favorable position for the entrance of the blood vessels, and, as a consequence, the anterior vascular system preponderates over the posterior. The least vascular plane is shifted into the posterior half

of the kidney and coincides pretty accurately with the plane of the posterior row of calices. This is the type most favorable for the surgeon, and fortunately the overwhelming majority of kidneys are built according to this plan.

SIMILARITY OF FORM OF BOTH KIDNEYS.

There is a remarkable conformity of the two kidneys of the same individual. This conformity includes general outline, size and weight, degree of rotation, type of pelvis and calices, and type of vascularization. Hauch states that such similarity was even found between the two pairs of kidneys in twins. However, his case is too isolated to permit of any generalization (Figs. 83 and 85).

The similarity, it must be understood, is not a mathematical one, for there certainly are slight differences noticeable, which have prompted so great an investigator as Hyrtl to deny the existence of any conformity. The few cases, however, upon which Hyrtl based his conclusion are possibly exceptions to the above rule, which I can corroborate.

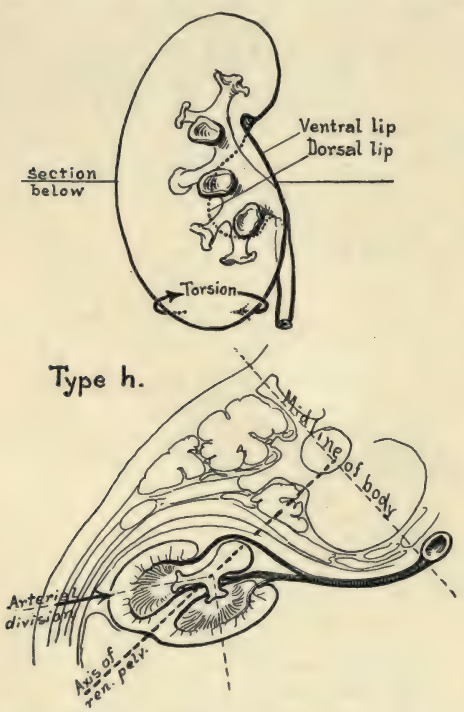


Fig. 94.—Same Type as in Fig. 93, Except That There is Greater Torsion of the Kidney. Note how this carries the calices with it.

SIZE, WEIGHT, AND CONSISTENCY.

The figures as given by the various authors differ considerably, and if compared with my own measurements it would seem that the differences in the average measurements were due more to the variations of the methods employed than to actual variations of the average measurements of the kidney. There is no misunderstanding as to the length and thickness of the kidney, but the breadth has been measured in two ways: (1) above the hilum, and (2) at the hilum. The former measurement is not at right angles to the periphery and gives an average dimension 1 cm. in excess of

the correct diameter, which is from the center of the more prominent lip of the hilum to the lateral border. The weight of the kidney has been measured in state of collapse and with vessels, pelvis, and peripelvic fat removed, and a difference of about 35 grams was noted when compared with the weight of the unmutilated kidney in state of normal distention with blood. The latter weight is the one to which we refer in the following:

Size.—I find that the average dimensions of the kidney in a state of physiological distention are as follows: Length, 11.4 cm.; breadth, 6 cm.; thickness, 3.9 cm.

A thick kidney is usually short, a thin kidney long, and thus we find the decrease in one dimension is associated with an increase in one or both of the others.

The maximum dimensions I find are: Length, 14 cm.; breadth, 7 cm.; thickness, 5.5 cm. All three of these measurements are, of course, not often found on one kidney, unless it be a case of compensatory hypertrophy, and then these figures are frequently exceeded. The longest kidneys are those with divided pelvis or double ureter and those with supernumerary blood supply. The broadest and thickest kidneys are the short ones, or those whose pelvis is found deep in the sinus renalis.

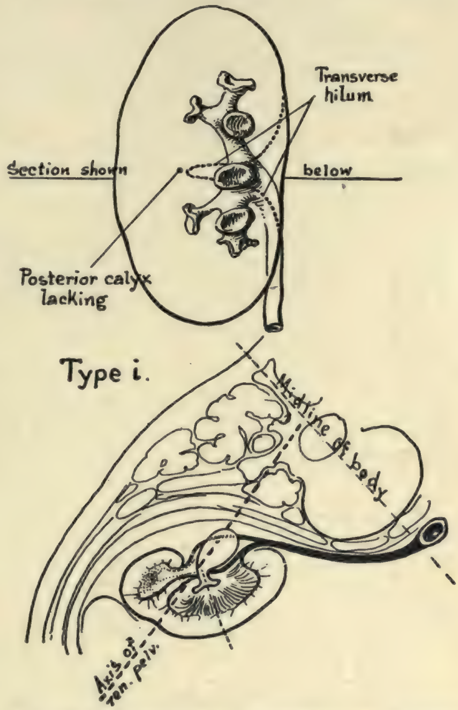


Fig. 95.—Excessive Rotation of Entire Kidney; Anterior Lip Projects Much Farther Than Posterior. Deep transverse notch on posterior surface associated with absence of middle posterior calyx. Anterior calices point mesio-anteriorly. Upper and lower posterior calices point slightly anterior to lateralward. Posterior arterial system very small. The contour of the kidney has again become elliptic.

The minimum dimensions in the adult I find are: Length, 9; breadth, 2.5; thickness, 2.5.

Weight.—The average normal weight in a state of physiological distention is 168 grams, which coincides fairly well with Sappey's figures, which give it as 170 grams. The specific gravity is 1.05 (Henle).

The minimum and maximum weights are 107 and 264 grams, respectively (Küster). The combined weight of both kidneys in the adult amounts to about 1/170 of the weight of the body, in the newborn 1/140, and in old age about 1/180. Figure 96 is a curve showing the average weight of both kidneys from birth to old age. The extensive studies of R. Thoma ("Untersuchungen über die Grösse und das Gewicht," Leipzig, 1882) coincide fully with these figures, except that his values are uniformly lower, owing to his method of

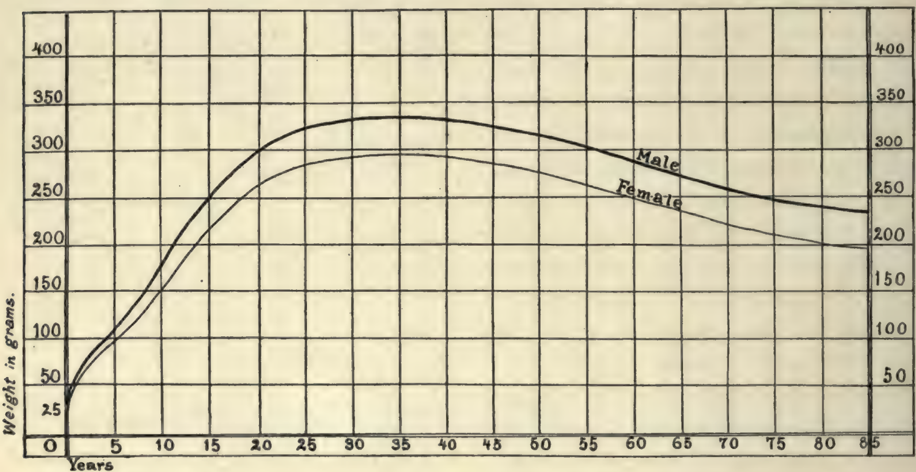


FIG. 96.—CURVES SHOWING COMBINED WEIGHT OF TWO KIDNEYS IN STATE OF PHYSIOLOGICAL DISTENTION, FROM BIRTH TO OLD AGE. These lines indicate the average weights. Variations in one-half of all cases in adults are not greater than 35 gr. In the other half, variations from 35 to 170 gr. occur.

weighing the parenchyma minus blood, capsule, vessels, fat, pelvis. The curve shows that the most vigorous growth of the kidney coincides with the period of most rapid growth of the body, viz., in the newborn. At that time the relative weight of the kidney is greatest. Then comes a period of less vigorous growth with the minimum at the sixth year, after which there is another rapid increase which reaches its maximum at the tenth year, the increase then becoming again more gradual until the greatest weight is attained at the thirtieth year. The decline sets in at forty, and proceeds very slowly to senile atrophy.

The right kidney is generally slightly smaller and weighs less than the left. The difference in size in the adult amounts to about 0.7 cm. in length, 0.2 cm. in breadth, and 0.2 cm. in thickness. The difference in weight is about 10 grams.

The kidney of the female is, as a rule, smaller and lighter than that of the male. The difference in size is about 0.5 cm. in length, 0.6 in breadth, and 0.2 in thickness. The weight differs about 20 grams in the single organ or 40 in both kidneys.

Consistency.—The consistency of a normal kidney in a state of physiological distention is characterized by a resistant softness and elasticity. In a bloodless state it becomes flabby. The tissue is not of equal density throughout, for on palpation one can frequently distinguish between the harder pyramidal substance and the more yielding cortical columns. The thinner the peripheral layer of cortex, the easier will be the palpation. This method is of especial value if the surface markings, such as the furrows of lobulation and the stellate veins of the capsule, are indistinct. In cases of abnormal distention of the pelvis, such as beginning cases of hydronephrosis, pyonephrosis, or tuberculosis, the conditions are reversed and the cortical columns are found more resistant than the flattened out or destroyed pyramids. The sinus renalis is often the carrier of a large amount of fat, extending all the way up to the papillæ, and it is owing to this elastic fat bolster in the interior that such kidneys appear excessively soft and yielding.

PELVIS OF THE KIDNEY.

I. Forms Characteristic to Animals.—According to Hyrtl ("Das Nierenbecken der Sängethiere und des Menschen," Wien, 1870) the types of pelvis in mammalian kidneys are conveniently divided into two large classes, viz.: (1) tree-like branching ureters without formation of a definite pelvis, a form always found in lobulated kidneys; (2) well-developed pelvis with or without leaf-like attachments, a form found only in smooth kidneys. The anlagen of both types, as Toepper [1] has pointed out, are the same. The difference in the ultimate forms is caused by the varying disposition of the parenchymal growth.

Toepper's classification, which is more elaborate, is as follows:

(1) Simple or primitive pelvis as found in the lowest order of mammals. It is merely an oval pouch without any secondary cavities. Type form found in Ornithorhynchus Paradoxus. Examples of same, Monotremes, Marsupials, and Edentates.

(2) The ramifying ureter. Examples: Seal, porpoise, whale, bear, cow (Fig. 97), and, in less emphasized degree, man.

The maximum number of calices in mammalia appears to be 300-400 in

[1] P. Toepper. "Untersuchungen über das Nierenbecken der Sängetiere." (*Arch. f. wissensch. u. prakt. Thierheilk.*, Berl., 1896, xxii, 241.)

the seal (Owen: "Comparative Anatomy," III); the maximum reached by any other mammals is 50-60, in the cow. In the human kidney of this type may be found as many as 18 calices (Hyrtl). The calices, as a rule, receive each one papilla, although twin calices are not infrequently observed.

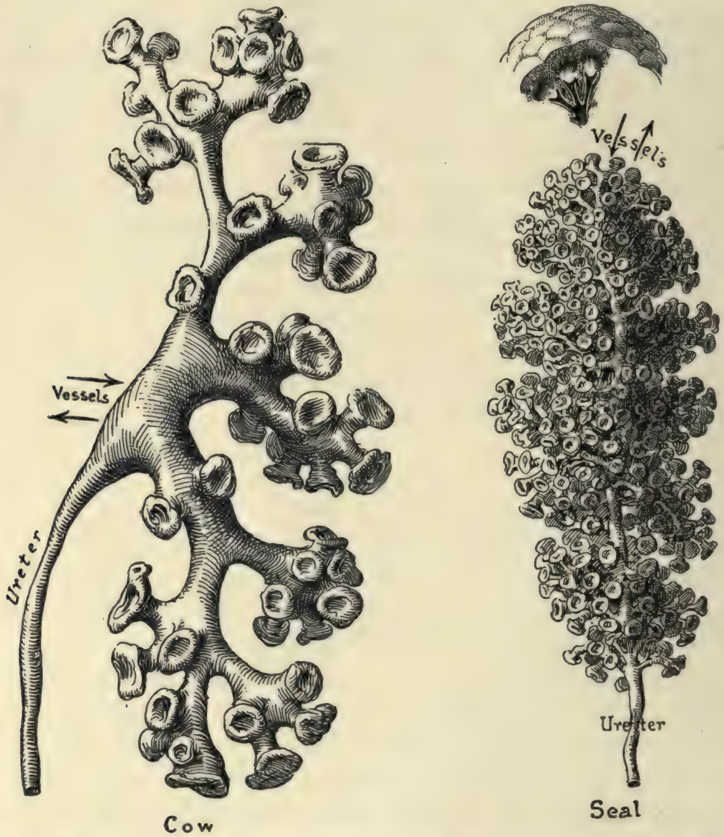


FIG. 97.—DIAGRAMS OF CASTS OF RENAL PELVES AND CALICES IN THE COW AND SEAL. (After Hyrtl.)

The calices are relatively longest and narrowest in animals that have the greatest number, viz., the seal (Fig. 97). Each calyx receives the papilla of a little pyramid, surrounded by a distinct cortical layer. Thus, in each lobule we find a perfectly independent little kidney with hilum, cortex, and medulla. On account of the marked lobulation the older anatomists have compared such kidneys with a bunch of grapes, the individual berries of which are crowded

against one another. The ureteral system resembles the stem with its branches after removal of the grapes. The vessels of such kidneys either enter together with the ureter or at some other portion of the kidney. In the seal they plunge into the parenchyma at a point diametrically opposed to the place of exit of the ureter.

Human kidneys with this type of pelvis are inclined to display lobulation, but I have also found it lacking.

(3) Pelvis with leaf-like attachments. Examples: Dog (Fig. 98), sheep, llama, antelope, hare, rat, cat, and, in modified form, monkey and man.

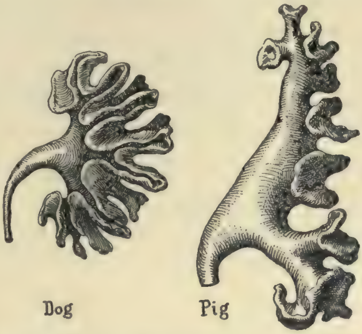


Fig. 98.—Diagrams of Casts of Renal Pelves in the Dog and Pig. (After Hyrtl.)

The pelvis of the dog shows the leaf-like prominences very well. It may therefore serve as a type form. The capacious pelvis has on its lateral border an anterior and posterior row of 4 leaf-like prominences which curve toward the hilum. One similar leaf-like extension curves toward the hilum from the upper, and one from the lower, pole. Thus, we have 10 such extensions, the spaces between which are occupied by the large blood vessels, radiating from the hilum to the periphery. It is of interest to note that the posterior division of the arterial tree in all these types is larger than the anterior, a condition which is just the reverse of that found in man. If the kidney has two separate renal arteries, one always belongs to the anterior, the other to the posterior, surface.

The anterior view of a corrosion preparation of the dog's pelvis is identical with the posterior, the two systems extending equally far laterally. In a hare or rabbit's kidney, however, the posterior row of leaf-like protuberances extends further out, and as a consequence the anterior arterial tree preponderates in size. Thus, we have an example of the exact conditions prevailing in man.

The pelvis of the kidney in the lion and tiger is similar to that of the sheep, except that the ureter near the pelvis has a spiral arrangement.

(4) Pelvis with tubular prolongations. Examples: pig (Fig. 98), tapir, rhinoceros, elephant, monkey, and man.

The pelvis of a pig is devoid of the typical leaf-like extensions and presents instead one or two rows of short calices with broad recurving fornices which, if especially well developed, resemble leaf-like processes. Figure 98 is worthy of note in that the upper branch of the pelvis is the larger, and not the lower, as in man (Hyrtl). As a whole the pelvis of the pig has a

character quite similar to that of the human. The fornices are regular in shape, but the arrangement of the papillary depression is concentric and not eccentric, as in man.

Corrosion preparations of the pelves of the horse, elephant, and rhinoceros present a unique appearance, inasmuch as the ducts of Bellini, owing to their large caliber, become easily injected. The casts of the upper and lower collecting channels of the pelvis are not unlike the hair on a squirrel's tail. Except in the case of the elephant, where there is a slight tendency to papillary formation, there are no papillæ in such kidneys. There are, especially in the rhinoceros, many individual lobes, with cortex and medulla, but without separate papillæ, since the tubules converge to open in the upper and lower pelvic branches.

The pelvis of the monkey and of man are, as might be supposed, very similar. It is important to bear in mind that, while within the confines of one order differences as to type of pelvis exist, we may find the same type in representatives of different orders. On careful inspection of a large series of injected and corroded pelves of human kidneys it becomes evident that in the human pelvis the range of variation is far greater than is the case in the pelves of any of the classes of animals. In fact, most of the types found in animals are represented in the human series, though in a less pronounced degree.

II. Forms of Pelvis Characteristic of Man.—The variations to which the renal pelvis is subject are so extensive that it is impossible to find two pelves absolutely similar. The variations are in regard to: (1) number of pelves; (2) number of major calices; (3) number of minor calices and papillæ; (4) location of pelvis in regard to the hilum; (5) size of pelvis and calices; (6) shape of pelvis and calices; (7) direction of pelvis and calices.

(1) The Number of Pelves in One Kidney.—As a rule there is but one distinct pelvis. In cases of double ureter, however, there are two, and if the ureter divides some distance from the hilum the same condition exists. The lower division is usually the larger and appears as a distinct pelvis, while the upper generally retains the form and caliber of the ureter (Hyrtl's "Halbes Nierenbecken"). External indications of a divided or double pelvis are: a long hilum, a long kidney, an especially deep transverse groove on the surface, marked lobulation; finally, abnormal blood supply. All these signs, however, rarely exist together.

(2) The Number of Major Calices.—There are usually only two, an upper and a lower. There may, however, be a third major calyx arising from the pelvis between the upper or lower calyx, or both may give rise to another

major calyx, and we have three or four. Finally, the distention of the pelvis may involve the major calices, in which case they partly or entirely disappear. There are no external indications to demonstrate the number of major calices, except in cases where they are visible at the hilum.

(3) THE NUMBER OF MINOR CALICES AND PAPILLÆ.—The number of calices varies between 4 and 12, with the most prevalent number of 8. The relative frequency is as follows:

In 1	per	cent.	of	cases	there	are 4	calices
2	"	"	"	"	"	" 5	"
9	"	"	"	"	"	" 6	"
18	"	"	"	"	"	" 7	"
28	"	"	"	"	"	" 8	"
17	"	"	"	"	"	" 9	"
15	"	"	"	"	"	" 10	"
6	"	"	"	"	"	" 11	"
4	"	"	"	"	"	" 12	"

Some authors state that the average number of calices is 6, a discrepancy which is possibly accounted for by their failure to study casts of the pelvis, since in an uninjected pelvis a calyx may readily be overlooked; or else they failed to regard a short calyx as such, and counted it simply as a fornix or papillary pouch. From a study of a large number of kidneys by Hauch, it becomes evident that the average number of calices in the female is less than in the male. Age, as may be supposed, has no influence.

The number of papillæ is usually in excess of that of the calices, since there may be twin or triple papillæ in the upper and lower calices, or in one or several of the others. The greatest number of papillæ is found in kidneys with very active down-growth of cortical substance in the form of secondary and tertiary columns of Bertin. Wherever a column has reached the sinus renalis a double papilla results. The figures per cent. are as follows:

In 1	per	cent.	of	cases	there	were 4	papillæ
3	"	"	"	"	"	" 5	"
5	"	"	"	"	"	" 6	"
19	"	"	"	"	"	" 7	"
35	"	"	"	"	"	" 8	"
12	"	"	"	"	"	" 9	"
10	"	"	"	"	"	" 10	"
10	"	"	"	"	"	" 11	"

In 2 per cent. of cases there were 12 papillæ
1 " " " " " " 13 "
1 " " " " " " 14 "
1 " " " " " " 18 "

Again, the number of papillæ is greater in the male than in the female, the difference in the average number being one papilla. There is no absolutely safe method of determining the number of calices and papillæ on inspection of the kidney. It is an advantage, however, to remember that nearly all normally shaped kidneys have 6-8 calices, and that a larger number of calices is found in abnormally shaped kidneys or kidneys with divided pelvis and double ureter.

(4) The Location of the Pelvis.—The pelvic dilatation of the ureter may be found (a) entirely inside the renal sinus, in which case it is invisible at the hilum; (b) just at the hilum, protruding some distance from it; (c) entirely outside. The relative frequency of the three conditions is in the order mentioned. The center of the pelvis is usually situated below the middle of the kidney. Furthermore, the pelvis may be in front of the kidney, at the median border, or at the mesio-posterior region of the hilum, with innumerable transitory forms. The mesio-posterior position is by far the most frequent.

The location of the pelvis affects the length of the major and minor calices, viz., they are shorter in the case of an intrarenal pelvis.

(5) The Size of the Pelvis and Calices.—The caliber of the pelvis and its branches, measured from the point where the ureter begins to dilate, is naturally very varying, and measurements of its capacity yield figures ranging between 2.3 c. c. and 2,000 c. c. or more. This enormous size, of course, is pathological and found only in advanced cases of hydronephrosis; while in pyonephrosis, tuberculosis, and other processes distending the pelvis or breaking down its barriers, the figures are lower.

The largest measurement in a kidney of apparently normal exterior was 33 c. c., but this is, I think, surely a decidedly abnormal capacity. The greatest number of pelves with their calices measured from 5-10 c. c., with 7.5 as the most frequent figure. Any distention between 10 and 20 should be regarded as abnormally large and beyond 20 as pathological.

The infantile pelvis is relatively smaller than the adult, since the parenchyma surrounds it tightly on all sides and there is little or no elastic fat bolster in the sinus. In old age the pelvis again becomes slightly smaller, especially the calices, which become stretched through shrinkage of the pyram-

idal substance, thus drawing the papilla away from the calyx. This process causes the fornices to disappear and renders the calices relatively narrow.

The renal pelvis in the male exceeds in capacity, as a rule, that of the female, although exceptions are frequent. It is especially noteworthy that pregnancy causes a noticeable distention of the pelvis and calices, which persists for some time after the birth of the child.

The extrarenal pelvis protruding at the hilum is usually larger than the intrarenal pelvis, the single pelvis larger than the divided pelvis or the pelvic distentions of a double ureter. The upper division in such cases is usually of the caliber of the ureter, while the lower forms a small pelvis. The relative capacity of the two divisions is about 1:3. The two pelves of the horseshoe kidney are found approximately of the same size, although in asymmetrical types there is a marked difference. The capacity may be only slightly above normal, but may also reach a size double or three times that of a normal pelvis.

There is no relationship between the number of calices and fornices and the capacity of the pelvis.

The linear measurements of the various corresponding parts of the renal pelvis and calices of many individuals also yield no definite figures. For instance, the cranio-caudal diameter of the pelvis at its entrance in the hilum may measure as little as 6 mm., and, again, I have found it 45 mm. long. In the majority of cases, however, it measures between 15 and 20 mm. The ventro-dorsal diameter of the pelvis measures between 0.5 and 2.5 cm. or more. The most constant of all the measurements is that of the entire length of pelvis and calices from cranial to caudal fornix. This measurement I found varying only between 5 and 8 cm., with by far the greatest number of casts measuring 6 cm. The length and the diameter of the calices likewise is variable. The length of both major and minor calices is insignificant in cases of distention of an intrarenal pelvis. The fornices then are immediately attached to the dilated pelvis. On the other hand, the length of the calices may be considerable in cases of extrarenal pelvis, the major calices measuring 3-4 cm. in length, the minor calices 2-3 cm. The direction in which the minor calices point determines largely their length; thus the calices pointing laterally are usually of greater length than those pointing anteriorly. The usual length of the minor calices in the most common form of posterior pelvis is 1-15 cm. for calices of the posterior row and 0.3-1 cm. for calices of the anterior row. The length of the cranial major calyx exceeds that of the caudal. The diameter of the major calices varies between 3 mm. and 15 mm. or more, 6 mm. being the usual measurement. The minor calices measure from 1-10 mm., with 5 mm. as the most frequent diameter.

The capacity of the pelvis *intra vitam* is easily determined by injection through an ureteral catheter, the onset of pain marking the maximum distention of the pelvis. See Chapter XVII.

(6) THE SHAPE OF THE PELVIS AND CALICES.—(*a*) Single Pelvis.—A single pelvis as seen from the posterior surface is usually triangular in outline, the base of the triangle being inside the renal sinus parallel with the length axis of the kidney, the apex pointing downward into the ureter. The two sides of the triangle are curved in a mesial direction, the upper more so

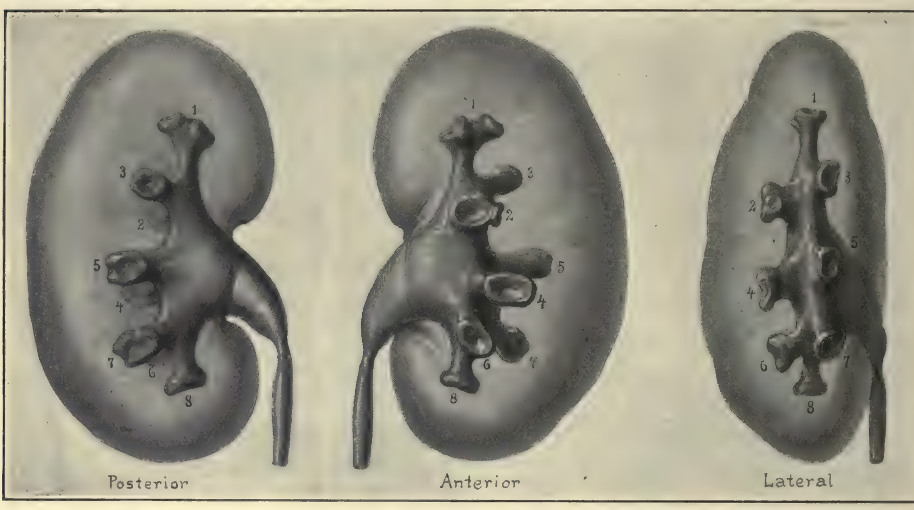


FIG. 99.—POSTERIOR, ANTERIOR, AND LATERAL VIEWS OF CAST OF PELVIS AND CALICES OF HUMAN KIDNEY.

than the lower. The thickest portion of this triangular pouch is, as a rule, just outside the hilum.

From this pelvic pouch the major calices arise, one leading into the upper half of the kidney, one into the lower, and, as is sometimes the case, in addition to these two, a third leading into the middle portion of the kidney. Branching out from these major calices or from the pelvis direct we find the minor calices.

The simplest forms from an anatomical, as well as from a surgical, standpoint are those single pelves where the dilatation has involved the major calices and the minor calices empty directly into the large common pouch (Fig. 99).

There are one upper and one lower polar calyx and two longitudinal rows of 2-3 calices each. The total number of calices in these forms, therefore, is 6,

7, or 8. The individual calices of the anterior row are either higher or lower than those of the posterior row, rarely on the same level. In very few instances the two rows of calices have one common base line at the pelvis. The individual calices then are usually of considerable length. Their peripheral portion curves away from the common plane, some turning ventrally, others dorsally. For instance, if there are four calices in a row, 1 and 3 may turn dorsally, 2 and 4 ventrally; or 1 and 4 dorsally and 2 and 3 ventrally. The latter type is associated with a deep transverse parenchymal cleft on the dorsal surface.

The form next to be considered is the pelvis with three major calices. The upper and lower each have 3 or more minor calices, arranged similarly to the corresponding regions in the last-described form, viz., the polar calices in the mid line, the other two in the planes of the two rows. The middle major calyx arises from the pelvis direct and either remains single in kidneys with deep transverse groove at the hilum, or divides into two or more minor calices.

The pelvis with two major calices is the form commonly referred to in the text-books. The two divisions may be of the same size, or one may be larger than the other. The larger one, which is, as a rule, the lower, usually receives the greater number of minor calices. The upper division is nearly always longer than the lower. The arrangement of the calices, again, is, with but few exceptions, in two longitudinal rows, with polar calices in the central plane.

Between this type and the next are many gradual transitions, and it is often difficult to draw the line between single bipolar pelves and double or divided pelves.

(*b*) Divided Pelvis.—This term is chosen merely for convenience sake, since, strictly speaking, nearly all pelves are divided. I refer here to those pelves whose division lies outside the hilum and whose major or minor calices enter the sinus renalis separately (see Fig. 459).

The simplest and also most frequent form is a division into two branches at varying distances from the hilum. To this category belong also the double ureters. A definite pelvis is generally lacking, although there is always a slight dilatation, more considerable if the division is near the hilum. The two divisions may be of equal size, but very frequently the lower branch is the larger and often forms a pelvis, while the upper continues in the thickness of the ureter.

The minor calices are frequently larger than the ureter or the major calices; they do not branch off from the major calices until the sinus is reached, then

they usually assume the regular arrangement in two longitudinal rows, with single polar calices.

More complex forms result if the external pelvis has more than two divisions or major calices, visible at the hilum, or, finally, if even the minor calices appear at the hilum. The pocket of the renal sinus in such cases becomes insignificant and may disappear entirely where the papillæ of the individual pyramids reach the hilum; then the entire renal pelvis with major and minor calices lies outside the hilum (see Fig. 459).

It is strange that, in all those variations of the proximal portions of the pelvis, the distal portions, such as fornices and papillary region, maintain a remarkable degree of regularity. They are nearly always grouped in two longitudinal parallel rows with single or composite upper and lower calices. It is very rare that three or four rows are found. The distances between fornices of equal size are fairly regular, the larger ones farther apart than the smaller ones. If large and small fornices are found in the same kidney the arrangement is irregular.

The shape of the calices may be cylindrical or conical, with the narrower portion at the pelvis. Frequently there are marked constrictions (1) at the point of junction of minor and major calices; (2) of major calices and pelvis, especially the upper; (3) of pelvis and ureter (Fig. 105). Further down we have the spindles of the ureter with similar constrictions, (4) at the crossing of the iliac artery, (5) of the uterine artery, and (6) in the bladder wall.

On the other hand, where calices join or where fornices fuse there may be a dilatation, which may reach considerable size. As a rule, such dilatations are found at the poles, and, on account of their size, they have been termed secondary pelves. In cases of divided pelves or double ureters these peripheral secondary pelves may be the largest pockets in the kidney.

Each calyx ends in a cup-shaped fornix with narrow or flaring leaf-like extensions or collars. Those of the polar fornices generally curve over toward the hilum, while those of the other fornices are directed transversely, exaggerating the curve of the renal surface, or point in no definite direction. Occasionally, a fornix may give rise to a small calyx. The fornices are most marked in the fetal stages and least in old age. That they entirely disappear has been denied, and the failure of some corrosion preparations to show the fornices has been explained by the obliteration of these delicate clefts with epithelial and other deposits that prevented the complete penetration of the injection material. Fornices are not always attached to the end of the calices. They may sit directly upon the pelvis or upon the side of a major or minor calyx.

The depression at the periphery of the fornix is caused by the papilla.

According to the shape of the papillary portion of the pyramid the depression is deep, shallow, or, as in beginning hydronephrosis, there may be no depression at all, but a prominence. The cast of the fornix then resembles a mushroom.

According to the extent of the papillary portions the fornix may be round, oval, dumb-bell-shaped (in the case of a double pyramid), or in the shape of a clover leaf (in cases of triple or quadruple papillæ). The complex forms are nearly always at the poles, usually the upper. The papillary depression, if single, is placed eccentrically in the fornix. In a few isolated instances the papillæ are situated directly upon the end or the side of a calyx or pelvis without the formation of a fornix.

There is great similarity in the form of the pelvis and calices of the two kidneys in the same individual. There are, however, no absolutely reliable external signs to indicate what form the pelvis and calices have, except in cases where a portion of the pelvis protrudes at the hilum. For all practical purposes, however, it suffices to remember that: (1) abnormal external form, (2) supernumerary vessels, (3) abnormal position of the entire organ, are the chief indications of an abnormally shaped pelvis and calices. On the other hand, a single extrarenal pelvis with the usual arrangement of 6-8 calices is always found in a normally shaped kidney.

I can confirm Hyrtl's observation of the formation of *diverticula of the pelvis.* Two were in the lower anterior wall of the pelvis, protruding into the sinus renalis and causing the vessels to form a large ring. The diverticula were of the size of a hazel-nut, with a constricted base. No pathological process could be demonstrated as cause of their formation. Other diverticuli in various places of the pelvis and calices were, however, clearly pathological. One in the anterior wall of the pelvis contained a calculus. Another was a hernial formation at the lower calyx, associated with disappearance of the parenchyma over a considerable area. In another case a cyst which had ruptured into the pelvis resembled a diverticulum.

(7) The Direction of Pelvis and Calices.—As shown on page 132 the direction of pelvis and calices is largely determined by the degree of kidney rotation. To recapitulate: the horizontal axis of the pelvis, which coincides with the anatomical axis of the parenchyma, may run (1) antero-posteriorly, (2) obliquely in a ventro-mesial to dorso-lateral direction, (3) laterally, and (4) obliquely in a dorso-mesial to ventro-lateral direction. There are innumerable transitions with the majority of pelves in the fourth direction. *The direction of the two vertical rows of calices in relation to the pelvic axis remains approximately the same; not so, however, in relation to the surface of the kidney,* for the "an-

terior" row may be found pointing (1) obliquely dorso-laterally, (2) laterally, (3) obliquely ventro-laterally, and (4) anteriorly; while the "posterior" row points in the corresponding cases (1) obliquely dorso-mesially, (2) dorsally, (3) obliquely dorso-laterally, and (4) laterally. Again, there are innumerable transition forms between 1 and 4, with the majority of cases showing the fourth-mentioned arrangement.

The division of the pelvis into a cranial and caudal branch, or major calices, takes place under the formation of an angle varying from 45 degrees to 180 degrees, or sometimes even more, with the overwhelming majority branching at an angle of 60 degrees. The extrarenal pelves branch at a much smaller angle than the intrarenal pelves. A small angle means a deep transverse cortical column in the middle of the kidney, with shallower cortical columns toward the poles. The larger the angle becomes the more nearly equal in depth will the various transverse cortical columns be found, until they are all approximately of the same depth in cases of an angle of 180 degrees—i. e., if the upper and lower major calyx form a straight line.

The direction of the pelvis and calices is easily determined on surface inspection of the kidney (see Rotation of the Kidney, page 130).

THE STRUCTURE OF THE KIDNEY.

I. Macroscopic (Fig. 100).—The kidney has been likened to a thick-walled pocket whose entrance is the hilum. The walls are the parenchyma, the central cavity the sinus renalis.

Sinus Renalis.—The sinus renalis is flattened in an antero-posterior direction, and contains the arteries, veins, nerves, lymphatics, and the renal pelvis with its branches. All these structures lie embedded in a varying amount of fat, which through the hilum becomes continuous with the adipose capsule of the kidney.

Fibrous Capsule.—The fibrous capsule, or tunica fibrosa renis, covers the outer surface of the kidney as well as the wall of the sinus. It consists of two thin layers loosely connected so that the outer layer is easily stripped off. The outer layer, measuring 0.1 to 0.2 mm. in thickness, is reflected over the vessels at the hilum, which it envelops. The inner lamella, known as tunica muscularis, measuring only 0.025 mm., is intimately attached to the kidney substance and consists of dense connective tissue with a deeper incomplete layer of smooth muscle fibers. Together these structures form a network of delicate strands, which is continuous with the connective tissue strands of the cortex corticis of the kidney.

The individual structures of the kidney appear clearly on a longitudinal section from the lateral border to the hilum (Fig. 100). The relationship of the contents of the sinus, arteries, veins, or pelvis to one another and to the kidney substance is clearly shown and requires no description.

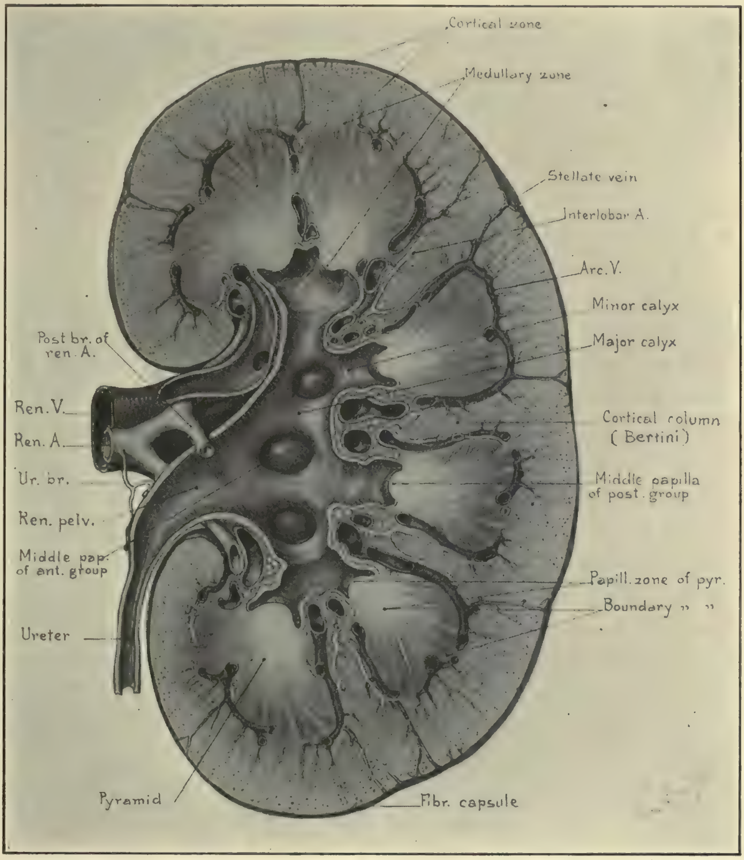


Fig. 100.—Longitudinal Section Through Human Kidney, Showing Gross Anatomy.

The Kidney Tissue.—The kidney tissue itself is seen to consist of a central striped medullary substance and a peripheral granular cortical substance. The cortical substance forms wedges which dip down into the medullary substance, dividing and subdividing it into smaller portions, the pyramids. According to Hauch the relative thickness of cortex and medulla

varies greatly, even in individuals of the same age. The actual measurements of the cortex in the adult vary between 5 and 11 mm., that of the medulla between 8 and 15 mm. This means at right angles to the anterior or posterior surfaces, viz., minimum thickness. The average relative measurement of the cortex as compared with the medulla amounts to about:

	100	per cent.	in	embryos of	2 months
	50	"	"	"	" 3 "
	30	"	"	"	" 6 "
from	22-31	"	"	newborn child	
"	40-60	"	"	child 1 year old	
"	40-60	"	"	" 7 years "	
"	40-75	"	"	the adult	

The Medullary Substance.—The pyramids are low, cone-shaped bodies with a broad convex base facing outward and a blunt point, the papilla, projecting into the sinus. The long diameter of the base is in a transverse direction and measures 4-6 cm. in the case of the dorsal pyramids, 3-4 cm. in the ventral pyramids. The dorsal pyramids are long and slender, the ventral short and thick. The apex is approximately 1.5 cm. away from the nearest point of the base, and, if one reconstructs a pyramid with an elliptical base 5 cm. long by 1.5 cm. broad and an apex 1.5 cm. high, situated over the lateral third of the base, one has a rather unfamiliar but nevertheless correct picture of a dorsal pyramid. The kidney possesses between 4 and 18, usually about 8, pyramids, of which the upper and lower are generally composite (double, triple, and quadruple). Almost all the pyramids are grooved at their base and assume the appearance of composite structures. The larger the number of pyramids in one kidney the simpler is their cone shape. In Figure 100 the pyramids are not cut at right angles to their base, hence the greater height. The polar pyramids, however, are higher, and, as already stated, usually of composite character. On section the pyramid is seen to be composed of an inner whitish papillary zone and an outer reddish-brown boundary zone. The outer zone shows a distinct striation, due to the diverging course of the lighter colored bundles of uriniferous tubules between darker colored bundles of blood vessels which radiate from the papilla-like reed grass from its root. The direction of these striated bundles is always at right angles to the surrounding layer of cortex; and, since most pyramids are nearly enveloped by cortex, it follows the divergence of the outer bundles must be considerable. Wherever a larger vessel is placed in their way the bundles

curve around it. This gives a peculiarly graceful wavy appearance to the striæ of the pyramid.

The papilla has, according to its size, from 7-50 ducts, whose openings can be detected with the aid of a low-power lens. Sometimes they are visible to the naked eye. In simple pyramids they are arranged over a circular or oval area at the summit of the papillæ. In composite pyramids the field of orifices may resemble a star. The average-sized single papilla has from 10-24, a larger single papilla 40, a composite papilla as many as 86 ducts (Hauch). The number of papillary ducts in the entire kidney varies between 170 and 216, with 200 as the average. The diameter of the orifice of the ducts is between 0.2 and 0.3 mm. Sometimes several ducts open together in a shallow depression of the papilla.

The Cortical Substance.—While the medullary substance is of relatively firm and dense consistency, the cortical substance is soft and granular. It tears easily and always at right angles to the surface, a fact to be borne in mind in suturing the kidney, either in nephrotomy or nephrorrhaphy. The color of the cortex is a dull reddish-brown, and on closer inspection a division in parallel bundles is noticeable, which appears as a continuation of the striæ of the pyramids. The lighter striæ, or medullary rays, are bundles of tubules coming from the pyramids, the darker striæ are bundles of glomeruli-bearing arteries with their accompanying veins. These two systems of striped bundles do not always run strictly parallel, since the vessels of one bundle frequently cross over to the neighboring one.

The cortex of the same kidney varies considerably in thickness; for example, the polar cortex is from 2-3 mm. thicker than the cortex on the ventral and dorsal surface. The thinnest portion of the peripheral cortex is at the center of each pyramid. Again, the cortex in the peripheral portions is thicker than in the columns of Bertin—i. e., between the pyramids, except in cases of divided pelvis, when the deep transverse column in the middle of the kidney may be of considerable thickness. The direction of the striation in these cortical columns is parallel to the kidney surface and not at right angles, as in the peripheral cortex (Fig. 100). It follows that at the junction between peripheral and columnal cortex the striation must assume a fan-shaped direction, narrow in the depth and broad toward the surface. The middle plane of each cortical column represents the terminus of the tubular structures from the two sides. On the surface this middle plane of the cortical columns is marked by the depressions of fetal lobulation, if such are present. Each cortical column, therefore, is made up of two independent layers of cortex belonging to the sides of two adjoining pyramids.

The wall of the pelvis and ureter consists of three layers: mucosa, muscularis, and an outer fibrous coat. The latter two coats are intimately connected. The total thickness of the wall of a calyx is 0.5 mm., of which 0.07 mm. fall to the mucosa. The mucous surface is of a pale brownish-pink with occasional bluish-white tints. In the narrow portions it appears folded in a longitudinal direction, as in the neck of the calices, at the junction between pelvis and ureter, and especially in the ureter itself. The plain muscle fibers which lie embedded in the fibrous coat or propria form a network of wide meshes, a miniature picture of those of the bladder. Their direction is circular, oblique, and longitudinal. An incomplete longitudinal layer is directly under the epithelium; this is surrounded by a relatively thick circular or oblique layer; and external to this by another, though incomplete, longitudinal layer.

The circular fibers form ring muscles or sphincters in the fornix—i. e., surrounding the papilla and again at the narrowest portions of the calyx, which they are perhaps capable of closing completely. Similar ring muscles exist at other narrowings further down, viz., major calyx, pelvis, ureter.

II. Microscopic (Figs. 101-104).—The minute anatomy of the kidney is thoroughly familiar to every student, and every text-book on the subject contains a clear description of the various structures composing the renal parenchyma, so we merely give a short résumé accompanied by a low-power and several high-power pictures of the individual structures.

The elements of which the kidney tissue consists are: (a) the uriniferous tubules; (b) the vascular channels, whose capillaries surround the tubules; (c) lymphatics and nerves; (d) the connective tissue holding within its meshes all these structures together.

(*a*) The Uriniferous Tubules and Pelvis.—As seen in Figure 101, the tubules consist of several portions which differ in regard to position, size, and cellular character. All tubules have a basement membrane and epithelium. Beginning at the blind peripheral pouch (Bowman's capsule), we have (1) the glomerulus, (2) the first convoluted tubule, (3) the descending and ascending limb of the loop of Henle, (4) the second convoluted tubule, (5) the junctional tubule, (6) the collecting tube, (7) calyx and pelvis. The relative positions of these various portions are clearly shown in Figure 101 and require no further description. The usual text-book figures of the course of the tubules are wrong in many respects, especially in regard to the relative positions of the convoluted tubules and glomerulus, but also in regard to the loop of Henle.

(1) The Glomerulus (Malpighian Corpuscle; Figs. 101 and 102).—According to the thickness of the cortical substance the number of glomeruli

varies between 7 and 17 layers. Usually there are 12-16 layers. Under layers we mean generations—i. e., the first generation nearest the medulla being the first layer, the second generation just peripheral to the first being the second, and so on up to the last or youngest generation, under the renal

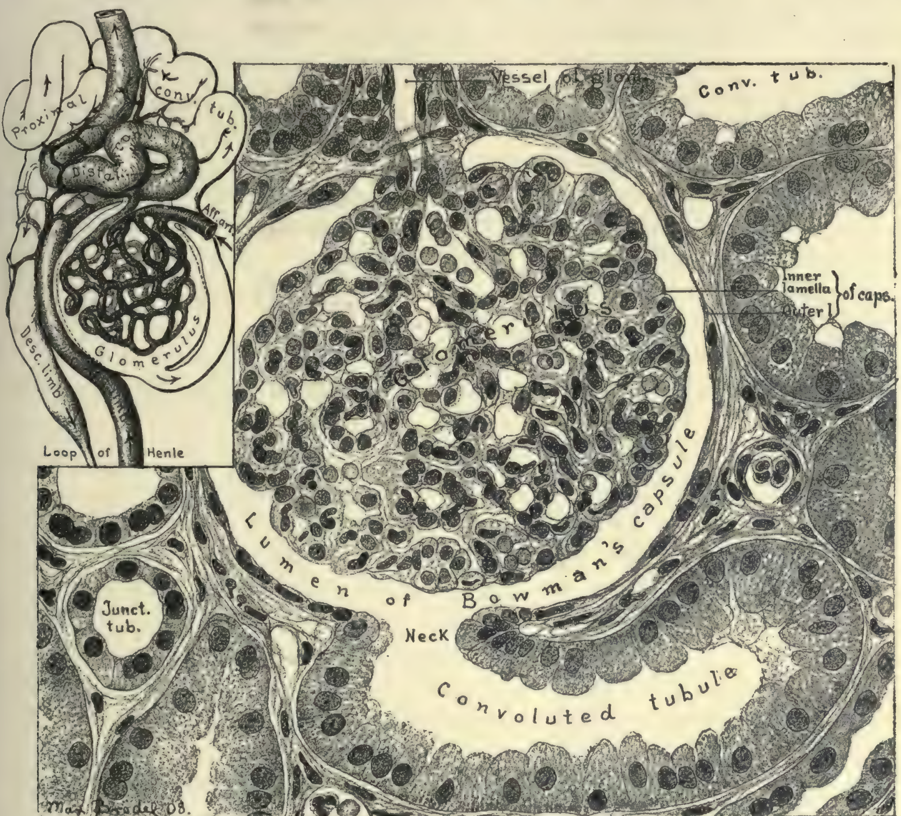


FIG. 102.—MICROSCOPIC SECTION SHOWING GLOMERULUS AND SURROUNDING TUBULES. × 625. The small diagram makes clear the architecture of the glomerulus capillaries. For the sake of clearness these vessels have been drawn much thinner than they really are.

capsule. The size of the glomerulus in the adult varies between 0.10 and 0.15 mm. in diameter; usually it measures 0.12 mm. If injected, its size increases to about 0.15 mm. The artery leading into the glomerulus (vas afferens) is slightly larger than the artery which carries the blood from it (vas efferens). Both enter and leave through the hilum of the glomerulus, found, as a rule, on the upper surface—i. e., the one nearest the renal capsule.

The glomerulus is a tuft of blood vessels, a small labyrinth of arteries of precapillary size. These are held together by connective tissue, and the entire globular structure is lined by a layer of flattened epithelium, with a membrana propria, which also dips into the clefts between the vascular loops. At the vascular pedicle this epithelial layer is reflected and lines Bowman's capsule, into which the glomerulus projects. Their relation is similar to a ball and socket. Between the two is a narrow lumen, which on section is crescent-shaped, the blind end of the uriniferous tubule.

(2) The First or Proximal Convoluted Tubule (Tubulus Contortus; Figs. 101 and 102).—Approximately opposite the entrance of the vascular pedicle into the glomerulus we find the neck of the capsule—i. e., a narrowing of the lumen between the glomerulus and the convoluted tubule. The epithelium changes abruptly from flat to cuboidal (becoming about 0.007 mm. thick—Disse[1]). The lumen of the neck is less than the thickness of its wall.

The neck suddenly passes into the convoluted tubule, the epithelium of which is a single layer of cuboidal cells of varying character (Disse). While some tubules have a narrow lumen and high epithelium, others have a wide lumen and a low one. In Figure 102 the two varieties are clearly shown. There are transition forms between these two types of tubules.

The epithelial cells in tubules with a narrow lumen are high and without distinct outline. The protoplasm is striped, darker near the membrana propria and lighter toward the lumen. The nucleus is paler than in the cells of other tubules. This type of tubule has been considered as inactive, since it is most frequent in cases of minimum urinary secretion (hibernating animals). The epithelial cell in tubules with a wide lumen has an outer portion or basis, containing the nucleus, and an inner portion projecting into the lumen. The protoplasm of the cell has a striped appearance, perpendicular to the basement membrane, due to rows of granules contained within the meshes of the protoplasm. The nucleus is round, has a membrane and deeply staining granules in a network of delicate chromatin. The nucleus measures about 0.006 mm. in diameter.

In the transitory forms the epithelium changes from the high to the low. The basis of the cell stains more deeply and the tip becomes pale, resembling a vesicle. In the absence of this vesicle the surface of the cells is lined by a ciliated membrane (M. Nussbaum, *Arch. f. d. ges. Physiol.,* 1878, xvii, 580). According to Kruse (*Arch. f. path. Anat.,* etc., Virchow, 1887, cix, 193), the upper margin of the cells is capable of transforming itself into a ciliated membrane.

[1] Von Bardeleben, "Handbuch der Anatomie des Menschen," Jena, 1902.

Except for the neck and first coil the entire first convoluted tubule lies peripheral to its glomerulus (Fig. 101). The last portion of the first convoluted tubule has a straight downward course. As it lies nearer the middle of the medullary ray than the glomerulus and the rest of the convoluted tubules, it mingles with the collecting tubules. It is, however, not difficult to distinguish one from the other, since the epithelium of this straight end segment is exactly like that of the convoluted tubules. At a varying distance from the glomerulus the end piece of the convoluted tubule suddenly narrows down to the descending limb of the loop of Henle.

(3) The Loop of Henle (Figs. 102 and 103).—The first portion of the descending limb is rather thick and its cells appear similar to those of the preceding portion. Further down, however, the descending limb has a narrow lumen and is lined by a low, flattened, clear epithelium. There is often only one cell seen to surround the small lumen, or, if not quite large enough, a portion of the neighboring cell fills the gap. The middle portion of each cell containing the oval nucleus projects into the lumen in the interspaces between the opposite cells, an arrangement which gives the lumen a peculiar wavy character. Huber (*Am. J. of Anat.*, 1904-5, iv, suppl., 50), however, asserts that in perfect specimens this peculiarity of the epithelium does not exist, and that during life the cells possess a more uniform thickness and the lumen is straight. The narrow portion usually changes into a wider portion before the actual turn of the loop is reached, often even a considerable distance from it. The transition, however, may also be at the loop itself or in the ascending limb. The epithelium changes into an irregular cubical or short columnar, with rather indistinct cell-boundaries. The base of the cell is faintly striated and darker than the inner portion, which has a very light center. The nucleus is round or oval and placed at the junction between the dark and light zones.

FIG. 103.—THE LOOP OF HENLE. × 625.

(4) The Second or Distal Convoluted Tubule (Fig. 102).—

The coils of the second or distal convoluted tubule are also found peripheral to the glomerulus and mingled with the coils of the first convoluted tubule; but, as G. Carl Huber (*Am. J. of Anat.,* 1904-5, iv, suppl., 50) has pointed out, usually nearer the glomerulus. A recognition of this fact should aid in studying an individual glomerulus and its tubular system in a single microscopic section. The coils of tubules always rest like a cap on their glomerulus.

The cellular structures are similar to those of the ascending limb of the loop of Henle, except that the outlines of the cells are clearer.

(5) The Junctional Tubule (Fig. 101).—The junctional tubule connects the second convoluted with the straight collecting tubule. The length of the junctional tubule varies according to the position of the glomerulus. The nearer the periphery the shorter is the tubule. Its epithelium resembles that of the preceding section, except that it is lower. On this account the lumen of the junctional tubule appears slightly larger.

(6) The Collecting Tubule (Figs. 101 and 104).—The course of the collecting tubules is fairly straight, extending from the periphery of the medullary ray to the point of the papilla. In its course through the cortex it receives the junctional tubules of its territory; further down—i. e., in the boundary zone—it unites under an acute angle with other collecting tubules, the resulting tubes again unite with others, and so forth. It becomes larger and larger until finally at the papilla it emerges as one of the papillary ducts.

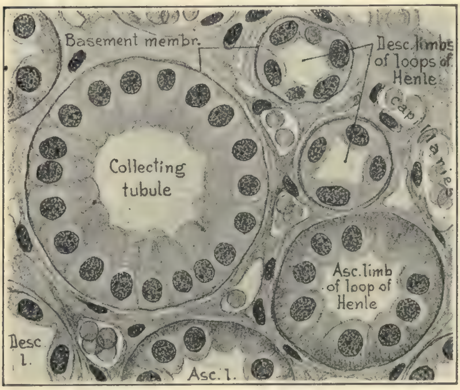


FIG. 104.—CROSS SECTION OF TUBULES IN PYRAMID. × 625.

According to Testut the average pyramid has at its base between four and six thousand collecting tubules, which result through 8 or 9 consecutive dichotomous branchings of about 20 papillary ducts. Each papillary duct carries, therefore, 250 to 300 collecting tubules.

The diameter of the papillary duct is between 0.3 and 0.2 mm. The collecting tubule in the papillary zone measures 0.054 mm.; its diameter in the boundary zone varies between 0.045 and 0.03 mm., while in the peripheral portion of the cortex it measures only 0.018 mm.

The lumen of the collecting tubules is cylindrical. The cells are sharply outlined, cubical or slightly cone-shaped. The protoplasm is clear, without

definite structure, and the globular nucleus is usually nearer the base of the cell. Since some of the loops of Henle dip far down into the papillary zone, sections of collecting tubules are usually surrounded by sections of the limbs of the loop (Fig. 104), except in the immediate vicinity of the papilla, where there are only collecting tubes.

The membrana propria is found on all the sections of the urinary channels from glomerulus down to collecting tubule, except on the largest tubes (from 0.1 mm. diameter on to the papilla), where it is, according to Disse, lacking. The epithelial cells of the papilla and papillary duct are identical and continuous.

According to Huber's calculations the entire length of a uriniferous tubule from glomerulus to junctional tubule is about 30 mm. The division is as follows:

	2.5-3	mm.	to	the	first convoluted tubule
about	12	"	"	"	descending limb of the loop
"	12	"	"	"	ascending " " " "
"	1	"	"	"	second convoluted tubule
	2	"	"	"	junctional tubule

The variations in length are caused by the position of the glomerulus, whether near the medulla (longer) or near the capsule (shorter); and by their relative position in the pyramid, whether in the interior (shorter) or near the sides (longer).

It may be of interest to add a few data as to the approximate number of glomeruli and the total length of the tubules in one human kidney. These figures are based upon actual count and calculation. There are about 40,000 collecting tubules of an average length of 2 cm.; total length, 0.8 kilometer, or 0.5 mile. The bulk of the cortex measures about 120 c. c., that of the medulla 30 c. c. There are about 20,000 lobules or units in a kidney, four-fifths of which reach to the surface, the rest being in the cortical columns. The number of glomeruli in one kidney is approximately 2,000,000. There are 2,000,000 uriniferous tubules of an average length of 3 cm. each; therefore, the total length of the uriniferous tubules from glomerulus to collecting tubule is 60 kilometers, or 37 miles. Both kidneys in the adult, therefore, contain 4,000,000 glomeruli, and the length of the entire tubular system amounts to 75 miles.

(7) Calyx and Pelvis.—In contradistinction to the epithelium of the papilla the epithelium of the calices and pelvis consists of several layers of polygonal cells with round or oval nuclei, with a surface layer of large flat

cells. These cells are flexible and their connection is such that they are capable of changing their relative positions according to the various degrees of expansion to which the tube is subjected. In areas of low pressure the layer is 6 to 8 cells thick, while in areas of distention it may be only one or two cells thick. Coming from the underlying stroma, connective tissue cells and elastic tissue strands penetrate the epithelial layer, thus securing close connection between the two layers. It appears, therefore, that the wall of the pelvis is by nature well equipped to withstand considerable changes in caliber without injury to its cellular constituents.

These penetrating strands of connective tissue form a network at the base of the epithelium. Between the meshes of this network epithelial nests may dip down into the propria and through contractions of the latter become nipped off. Such epithelial masses have been considered as glands, although they generally show no lumen. Their occasional presence explains the occurrence of cysts in the pelvis and ureter.

The muscularis causes ridges to project into the epithelial layer. There is an inner longitudinal, a middle transverse—i. e., ring-shaped—and an outer (incomplete) longitudinal muscle layer, and in the resulting square or rectangular depressions between these muscle bundles the epithelium exists in greater thickness. The middle system of vessels runs in these muscular ridges. The inner system, or superficial capillary network, projects into the tunica propria of the epithelial layer. The outer system consisting of the main trunks is found in the adventitia.

(*b*) The Vascular Channels (Figs. 101 and 102).—Under this heading will be described only the smaller vessels and the capillary system, leaving the description of the larger vessels for the sections on the surgical anatomy of the kidney.

Branches of the Renal Artery.—The branches of the renal artery lie in the sinus renalis on the ventral and dorsal surface of the pelvis. Some of the branches are directed toward the columns of Bertin in which they divide, others plunge directly into the cortex, until all have reached the base of the pyramids. Since these branches lie between the lobes of the kidney they are called "arteriæ interlobares."

Arteries of the Cortex.—At the base of the pyramids the arteries give off a vast number of delicate branches which run at right angles to the base of the pyramids parallel to and between the medullary rays. These are the "arteriæ interlobulares," the length of which varies between 4 and 8 mm., according to the thickness of the cortex. Their caliber varies between 0.1 and 0.3 mm. Frequently an interlobular artery crosses obliquely

from one lobule to another, as seen in Figure 101. At fairly regular intervals these arteries give off short curved branches, measuring about 0.03 mm. in diameter, the ends of which terminate in a glomerulus. In the periphery some of them give rise to a delicate branch to the capillaries of the convoluted tubules. The variations in the character of these afferent branches are pictured in Figure 101. In the glomerulus the artery divides into 4-6 short branches, which break up into a delicate network of precapillary size. The capillaries of the six branches usually anastomose with one another. In the center of the glomeruli they unite to form the efferent vessel, which, like the afferent, is always single. It emerges near the same place where the afferent vessel enters. The efferent vessel is slightly smaller than the afferent and soon breaks up into capillaries. The left lobule in Figure 101 shows the character of these vessels. The capillary network in the cortex is found in wide round meshes in the region of the convoluted tubules and in long narrow meshes accompanying the straight tubules. The end distribution of the interlobular artery is: (1) in branches to glomeruli; (2) in terminal twigs supplying the capillary network of the cortex corticis (i. e., the most peripheral layer of the cortex and devoid of glomeruli); (3) in perforating capsular vessels, of which there are two classes: small ones which have given rise to glomeruli-bearing arteries (Fig. 101), and large ones (seldom more than one in a kidney), which traverse the parenchyma without giving off any branches whatsoever. All the arteries up to the efferent branch have a distinct muscular coat. W. Z. Golubew (*Internat. Monatschr. f. Anat. u. Physiol.,* Leipzig, 1893, x, 541) found that the arteries of the deepest layer of the cortex form occasionally glomerulus-like labyrinths devoid of Bowman's capsule and without connection with the tubular system. These arterial networks are of various complexity: bipolar—i. e., they begin and end in an artery, or they may give rise to broad anastomoses with the venous system. Huber considers these vascular formations as retrogressive changes in the earliest generations of glomeruli.

Participation of Other Arteries than the Renal Artery in the Formation of the Cortex.—In isolated instances wedge-shaped portions of the cortex may be supplied from without (Hyrtl, "Das Nierenbecken der Sängethiere und der Menschen," Wien, 1870). A separate branch of the renal artery may curve around the surface of the kidney over a considerable distance and plunge into the cortex, until it has reached the base of the pyramids, where it breaks up into interlobular arteries.

I have found a similar arrangement quite frequently in cases of supernumerary arteries and in cases of congenitally low positions of the kidney.

Vessels of the Medulla (Vasa rectæ).—The arteries of the medullary substance or arteriolæ rectæ are bundles of six to twelve parallel vessels 0.02 to 0.03 mm. in diameter, of triple origin (Fig. 101). They arise (1) from the large arteries between cortex and medulla, or from the interlobular artery near its base; (2) as a branch of a glomeruli-bearing artery near the medullary zone; and (3) from the efferent artery of the lower glomeruli.

Hitherto, the vessels of the first and second types were considered by far the most numerous and therefore designated as arteriolæ rectæ veræ, in contradistinction to those of the third type, designated as arteriolæ rectæ spuriæ. As a matter of fact, almost all arteriolæ rectæ are efferent arteries from the lower glomeruli and only a very small percentage come directly from the arteries. Even these may, as Huber pointed out (G. Carl Huber, "The Arteriolæ Rectæ of the Mammalian Kidney," *Am. J. of Anat.,* 1907, vi, No. 4), be efferent branches of the lowest glomeruli which have disappeared. Huber's work was done on corrosion specimens of the kidneys of dogs, cats, etc., and I was able to corroborate his findings in the human kidney. The nomenclature of the arteriolæ rectæ should, therefore, be changed, viz.: those having traversed glomeruli should be arteriolæ rectæ veræ, while the few coming directly from the arteries should be called arteriolæ rectæ spuriæ.

The arteriolæ rectæ being grouped in bundles break up into capillaries as they proceed toward the papilla, the number of vessels in the bundle becoming less and less until only one or two are left, whose capillaries form a network around the large collecting tubes and papillary ducts. The capillaries of the papillæ anastomose with the vessels of the pelvis. The collecting veins (venulæ rectæ) are found in the same bundle with the arteriolæ rectæ, and this increases the total number of vasa rectæ at the base of the pyramids to 20 or 30 in each bundle. The veins frequently anastomose and are larger in caliber than the arteries. The individual character of these vessels, the short and the long circuit of their capillary system, is well shown in Figure 101.

Veins of the Cortex.—All the capillaries of the cortex drain into two sets of veins which empty into the arched veins between cortex and medulla. These two systems of cortical veins are the superficial and the deep.

The uppermost cortical capillaries drain into delicate ascending veins (the superficial veins, not accompanied by an artery). On the surface these veins of a given area unite in order to form star-like veins, the stellate veins of the capsule, whose diameter varies between 0.2 and 0.8 mm.; they spread out on the surface over an area varying from 0.25 square cm. to 2 square cm.

At the center of the star the stellate vein dips down into the cortex and becomes a vena interlobularis of especially large size, now accompanied by an interlobular artery and draining into the venous arch. On its way it receives numerous tributaries from all sides. The deep veins of the cortex, venæ corticales profundæ, constitute the majority of the venæ interlobulares and collect the capillary blood of the inner half or two-thirds of the cortex and drain likewise into the venous trunks between cortex and medulla. These veins are smaller than the interlobular veins, receiving stellate veins, and if seen in a corrosion preparation the large and small interlobular veins resemble a forest of minute palm trees in which the latter appear only as dense underbrush. The diameter of the veins is approximately twice that of the corresponding arteries.

The walls of the veins are intimately connected through connective tissue strands with the kidney substance, an arrangement which causes the lumen of the veins to remain always gaping (Disse: von Bardeleben's "Handb. d. Anat. d. Menschen," vii, 1902). The further course of the veins will be considered in the section on the surgical anatomy of the blood vessels.

The arteries of the kidney are end arteries, each wedge of tissue supplied by one artery being independent of the neighboring wedge, but note well that there are direct anastomoses between arteries and veins of precapillary caliber. According to Golubew they are found in the columns of Bertin, in the boundary zone of the medulla and at the junction of papilla and calyx.

The vascularization of the tendinous capsule is a wide-meshed capillary network such as seen in fasciæ. The arteries are small in caliber and derived in part from the interlobular arteries (Fig. 101), the end twig of which perforates the capsule, or they may be terminal branches of neighboring arteries; for example, the phrenic, lumbar, or adrenal arteries. The veins drain either through the stellate veins into the kidney or to the venous trunks in the vicinity of the organ. The arteries are frequently accompanied by two veins.

The vessels of the fatty capsule are perforating and recurrent branches of the renal artery, besides branches coming from the adrenal, inferior phrenic, 1st, 2d, and 3d lumbar, ovarian, ureteral, and celiac arteries, or from the aorta itself. With such free supply it is not surprising that the renal branches are often insignificant. If present, however, the perforating artery is usually large and tortuous, measuring from 0.5 to 1 mm. in diameter and 10 cm. and more in length. There is, as a rule, only one in a kidney, emerging from the parenchyma between two renal lobes, preferably at the lateral region of the anterior surface. It seems as though lobulated kidneys

are more prone to have perforating arteries than smooth ones. These vessels arise from the primary branches of the renal artery in the hilum, and, taking no part in the circulation of the columns of Bertin or cortex, they pierce the parenchyma. As a rule, there is no accompanying vein, the blood draining through the perineal plexus into the lumbar, ureteral, ovarian, and renal veins, and into the vena cava direct. Unlike the perforating artery, the *recurrent* arteries are constant. They are delicate branches coming from the renal artery inside the hilum, which form a sharp angle with the renal artery, run back for a distance and curve around the margin of the hilum. They traverse the fatty capsule at the mesial, lower, and anterior regions. They are very tortuous and their number is inversely proportional to their size. Occasionally they give off branches to the pelvis and the ureter.

Vessels of the Pelvis.—In a corrosion preparation the large arteries on the ventral and dorsal surface of the pelvis stand out as five or six ridges radiating from the hilum. The ridges mark the columns of Bertin and the depressions between the bodies of the pyramids. At the side facing the pelvis these large trunks give off a few small branches which supply the capillary network of the pelvis and calices up to the papillæ, which they surround in the form of a delicate wreath. There is a capillary communication between the vessels of this wreath and the papillary capillaries. Thus the circulation of the pelvis is in communication with that of the parenchyma.

The veins do not accompany the arteries, but run in the interspaces until finally they drain into the veins that surround the pelvis. The vessels to the pelvis may, however, also be derived from a larger branch of the renal artery itself, arising at the hilum and dividing into several trunks, one or two of which pass down the ureter.

(*c*) The Lymphatics and Nerves.—*Lymphatics of the Kidney.*—There is a superficial and a deep lymphatic system. The superficial lymphatics are in the fatty capsule and in the fibrous capsule, the deep lymphatics in the parenchyma. Occasionally branches from the deep system drain in the direction of the surface, but, as a rule, they accompany the larger vessels in the sinus to the hilum, where they emerge as large trunks, 2 to 8 in number (Disse). At the hilum they are joined by the ureteral and adrenal lymphatics. In their path they frequently traverse small intercalated glands. Finally, the lymph channels drain in the upper lumbar glands, a group of 15 to 30 glands situated around the aorta and vena cava over a distance of about 10 cm. The glands are arranged in three irregular rows, one middle and two lateral. The lymphatic channels coming from the fatty capsule,

according to H. Stahr ("Der Lymphapparat der Nieren," *Arch. f. Anat. u. Entwicklungsgesch.*, 1900, 41), empty directly into the lumbar glands, while those of the fibrous capsule communicate with the cortical lymphatics.

The lymph capillaries resemble the blood capillaries, except that they are of a more delicate structure, measuring 0.003 to 0.008 mm. in diameter. They are described as forming meshes around the convoluted tubules and dichotomously branching delicate vessels between the straight tubules of the medulla. The cortical capillaries drain in the direction of the glomeruli and afferent artery, forming larger vessels which accompany the interlobular arteries until they finally empty into the lymphatic plexus at the border between cortex and medulla, which also receives the tributaries from the pyramids. The further course is with the interlobar arteries toward the renal sinus and hilum.

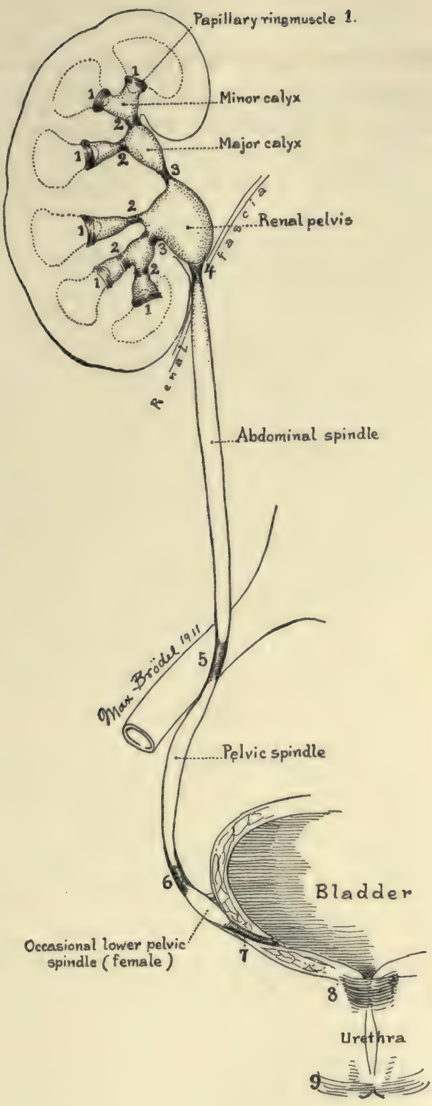
Nerves of the Kidney.—The kidney is richly supplied with nerves, both sensory and motor, which enter with the arteries at the hilum. They come from the renal plexus and the lesser splanchnic nerves. Around the arteries they form a network which accompanies them up to the afferent artery of the glomerulus. In their course they give off delicate branches to the muscular coat of the arteries. From the afferent arteries the nerves continue as a delicate plexus over the glomeruli, convoluted tubules, and straight tubules. As v. Smirnow ("Über d. Nervenendigingen d. Nieren," *Anat. Anz.*, 1901, xix, 347) has pointed out, they pass as fine threads along the basement membrane, sending off minute twigs, which encircle the tubule until they finally terminate in the form of delicate trees either on the membrana propria, or, perforating the same, they end free between the cells.

The nerves of the medulla come from the plexus around the vessels at the base of the pyramids. They are a network of wide meshes which sends branches to the vessels and the tubules. The epithelium of the collecting tubules contains nerve-endings. A few delicate fibers continue to, and end in the epithelium of the papilla.

(*d*) Connective Tissue of the Kidney.—All the structures composing the kidney, viz., vessels, tubules, lymphatics, and nerves, are woven together by a reticulum, consisting of a network of delicate and coarser fibers, which on the surface is continuous with the fibrous capsule. This reticulated framework is most strongly developed around the larger vessels, dense but delicate on the membrana propria of tubules and glomeruli, and very delicate around the capillaries.

The cortex contains less connective tissue than the medulla. The greatest density is found in the papillary zone where the number of tubules is few.

Fig. 105.—Diagram of the Urinary Tract in Women, Showing a Series of Well-Defined Compartments Separated from One Another by Little Ring Muscles Which Represent Thickenings of the Circular Coat in These Places. The condition has been shown considerably accentuated in order to illustrate the point. The first ring muscle (1) is seen encircling the papillæ; the second (2) at the neck of the minor calices; the third (3) at the neck of the major calices; the fourth (4) between pelvis and ureter; the fifth (5) at the crossing of the iliac vessels; the sixth (6) in the broad ligament; the seventh (7) in the wall of the bladder; the eighth (8) at the internal sphincter; the ninth (9) at the external urethral orifice. This is no ring muscle, although there is a narrowing of the lumen at the meatus. As the diagram shows, the ureter has several spindle-shaped dilatations between these ring muscles. The most marked constriction is found at (4); its narrowness is accentuated by the renal fascia passing over the uretero-pelvic junction, as shown.



Papillary ringmuscle 1.
Minor calyx
Major calyx
Renal pelvis
Renal fascia
Abdominal spindle
Max Brödel 1911
Pelvic spindle
Bladder
Occasional lower pelvic spindle (female)
Urethra

ANATOMY OF THE URETER.

Course.—Beginning at the renal pelvis each ureter runs downward slightly medianward and forward across the M. psoas, where it passes under the spermatic or ovarian vessels. The right ureter passes nearer the vena cava than the left does to the aorta, although the opposite arrangement has likewise been noted. This portion of the ureter is known as the abdominal part. At the point of crossing the iliac vessels, at or just lateral to their division between external and internal iliac, the two ureters are about 6 cm. apart, the nearest until they approach the bladder. Having crossed the iliac vessels, the portion known as the pelvic part begins. The ureters now suddenly curve backward and outward, following closely the contour of the pelvis. They pass in front of all the vessels, reaching their most lateral point when crossing the obliterated hypogastric opposite the ischial spine. Now running downward, then slightly forward and mesially, the ureters pass in the male beneath the spermatic cord, in the female beneath the uterine and the superior and middle vesical arteries, skirt the cervix and vaginal wall until they finally reach the trigonum of the bladder. Approaching it from both sides, the two ureters obliquely perforate the bladder wall for about 2 cm., until they open on the mucous surface about 3 cm. apart.

The ureters are covered in front by peritoneum, except when passing under the mesentery or extraperitoneal surfaces of the terminal ileum on the right side and the sigmoid flexure on the left.

Dimensions.—Varying with the position of the kidney, the length of the ureter may measure from a few centimeters in cases of ectopic kidney to 30 cm. in normal cases. The left kidney being usually on a higher level, the left ureter is on the average 1 cm. longer than the right. As may be supposed, the ureters in the male are slightly longer than those in the female, the difference being about 1 cm.

Male,	right	side	29.1 cm.,	left	side	30.2	cm.
Female,	"	"	28 "	"	"	29	"

On section the normal ureter appears as a flattened tube of a diameter of 4 to 6 mm., 5 being the average. The lumen is star-shaped, owing to the mucous folds projecting into it. The caliber is not uniform, but appears contracted in certain intervals, with long, spindle-shaped, gentle dilatations between these narrowings. The entire urinary tract from renal papillæ down to

vesical orifice shows a series of such constrictions, and it appears that they coincide with or are caused by the greater development of the circular muscle at these points. Whether these ring muscles, if well developed, are capable of completely shutting off the contents of the various compartments and producing a periodical emptying of each into the next one below, proceeding from the lowest compartment upward, is a matter of conjecture. It is interesting, however, to note the presence of these narrowings, and, as Figure 105

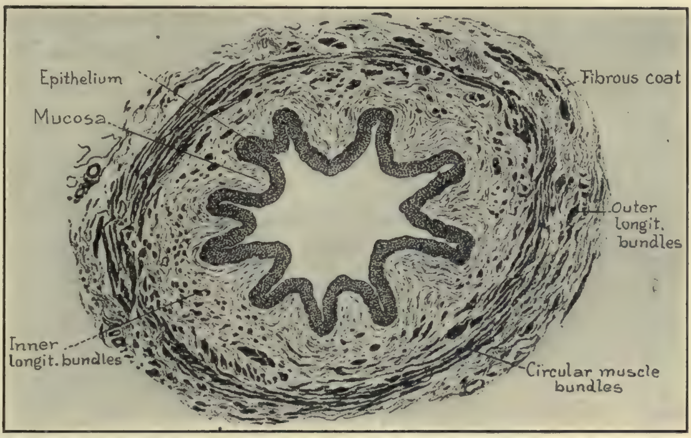


FIG. 106.—TRANSVERSE SECTION OF URETER SHOWING THE VARIOUS COATS, × 20. (After Piersol, Human Anatomy, 1907.)

shows, their arrangement is very significant. The capacity of the various compartments is approximately equal, the renal pelvis holding about as much as the abdominal spindle, the major calices as much as the renal pelvis, and the minor calices as much as the major calices. In most cases, however, the only ring muscle which appears at all capable of closing the tube is at the junction of the renal pelvis and ureter, the rest being too delicate in structure and too much stretched by prolonged distention of the canal.

Structure.—There are three coats, an outer fibrous coat, a middle muscular and an inner mucous coat (see Fig. 106).

The FIBROUS COAT is a loosely constructed envelope which begins at the renal papillæ, covers all of the calices, pelvis and ureter down to the bladder, where it blends with the fibrous covering of that organ. In the lower pelvic portion of the ureter this fibrous coat is especially thick, being reinforced by the adjacent connective tissue of the broad ligament. It appears as a well-defined sheath whose connection with the ureter is rather loose, thus permit-

ting ureteral peristalsis; indeed, it is probable that the peristalsis is the chief cause of the formation of the sheath.

The MUSCLE COAT consists of three layers of involuntary muscle fibers: an external longitudinal (incomplete), a middle circular, and an inner longitudinal. As mentioned before, the circular muscle coat is of greater thickness in the contracted parts of the ureter than elsewhere.

The MUCOSA consists of a tunica propria or submucosa, composed chiefly of fibro-elastic tissue and a "transitional" epithelium toward the lumen. The epithelial cells are cylindrical in the depth, becoming irregular, club- and spindle-shaped toward the middle, and change into flattened cells on the surface—i. e., at the lumen of the ureter. The thickness of the epithelium varies according to the degree of distention of the tube, 4 to 6 layers of cells being the usual arrangement. The individual cells are held together by strands of delicate fibers coming from the underlying stroma, thus permitting considerable changes of the form of the cells as in distention of the ureter, without impairing the integrity of the epithelium as a whole. In the non-distended state the mucosa is folded in a longitudinal direction, which is most marked in the contracted regions between the spindles.

The Vessels of the Ureter.—The ARTERIES are derived from the following sources:

(1) Small twigs coming from the renal artery or its lower branches. There are usually two of these, and they extend down only a few centimeters on the ureter.

(2) Short twigs from the spermatic or ovarian arteries; there may be one or two such vessels, or, if absent, their place is taken by a vessel coming directly from the aorta. It is not unusual to have the ureteral branches of both sides arise from a common trunk of aortic origin below the inferior mesenteric artery or at the bifurcation. These vessels supply the abdominal spindle of the ureter.

(3) Branches coming from the common iliac, anterior or posterior division of the internal iliac, or their further branches, such as the uterine and vaginal arteries. These vessels supply the pelvic portion of the ureter almost down to the bladder.

(4) Small twigs coming from the vesical arteries, either from the middle or inferior vesical, according to which of the two happens to supply the uretero-vesical region. These vesical twigs run up only a short distance, rarely more than 1 cm.

If we remember that the embryonic kidney during its ascent from the pelvis to the lumbar pocket is temporarily supplied by many small tributaries

coming from the aorta and its branches, also from the Wolffian arteries, it becomes more than probable, after the kidney has been vascularized from a higher aortic source, that some of these temporary renal vessels persist in the form of ureteral branches.

The number of ureteral arteries is inversely proportional to their size. Before entering the fibrous envelope of the ureter they frequently give off small branches to the surrounding peritoneum, subperitoneal tissue, and to the periureteral fat. A characteristic feature of the ureteral arteries is their free and broad anastomosis, which makes it possible to inject the entire plexus through any one of the above-mentioned individual arteries.

In the loose fibrous outer coat of the ureter the arteries form a plexus, consisting of longitudinal tortuous branches, from which at short intervals many smaller tributaries arise, anastomosing freely and penetrating the muscle coats of the ureter in many places. The arrangement is such that periodical contraction and distention of the canal do not injure its delicate blood supply. Having reached the submucosa, they form another more delicate plexus whose meshes are elongated in an up and down direction (Disse: von Bardeleben's "Handb. d. Anat. d. Menschen," 1902, vii, part I). From these delicate arteries the capillaries take their origin, those to the epithelium passing inward, while the muscle capillaries run outward.

The VEINS form a plexus in the submucosa which drains outward into the main trunks enveloped in the fibrous framework of the adventitia. These large ureteral veins are seen to anastomose freely with one another in the periureteral tissue and also with neighboring veins, such as the spermatic, or ovarian, the lumbar, renal, and, in the pelvis, with the uterine, vaginal, and vesical venous plexuses.

Lymphatics.—The lymphatics of the ureter are more numerous in the muscle coats and adventitia than in the mucosa and submucosa. They are seen to accompany the arteries and drain in three directions, the lower portion downward in the direction of the bladder, the pelvic and abdominal portion mesially into the pelvic and lumbar lymph glands, the upper portion in the direction of the renal lymphatics.

Nerves.—The nerves come from the sympathetic nervous system, being derived from the renal, inferior mesenteric, spermatic (ovarian), and hypogastric (vesical) plexuses. They form a delicate network around the ureter with microscopic ganglia at the upper and lower ends, the end twigs being mostly distributed in the muscular coats, although some fibers can be traced to the epithelium. According to Waldeyer, there are a few medullated fibers, which can be demonstrated among the non-medullated ones.

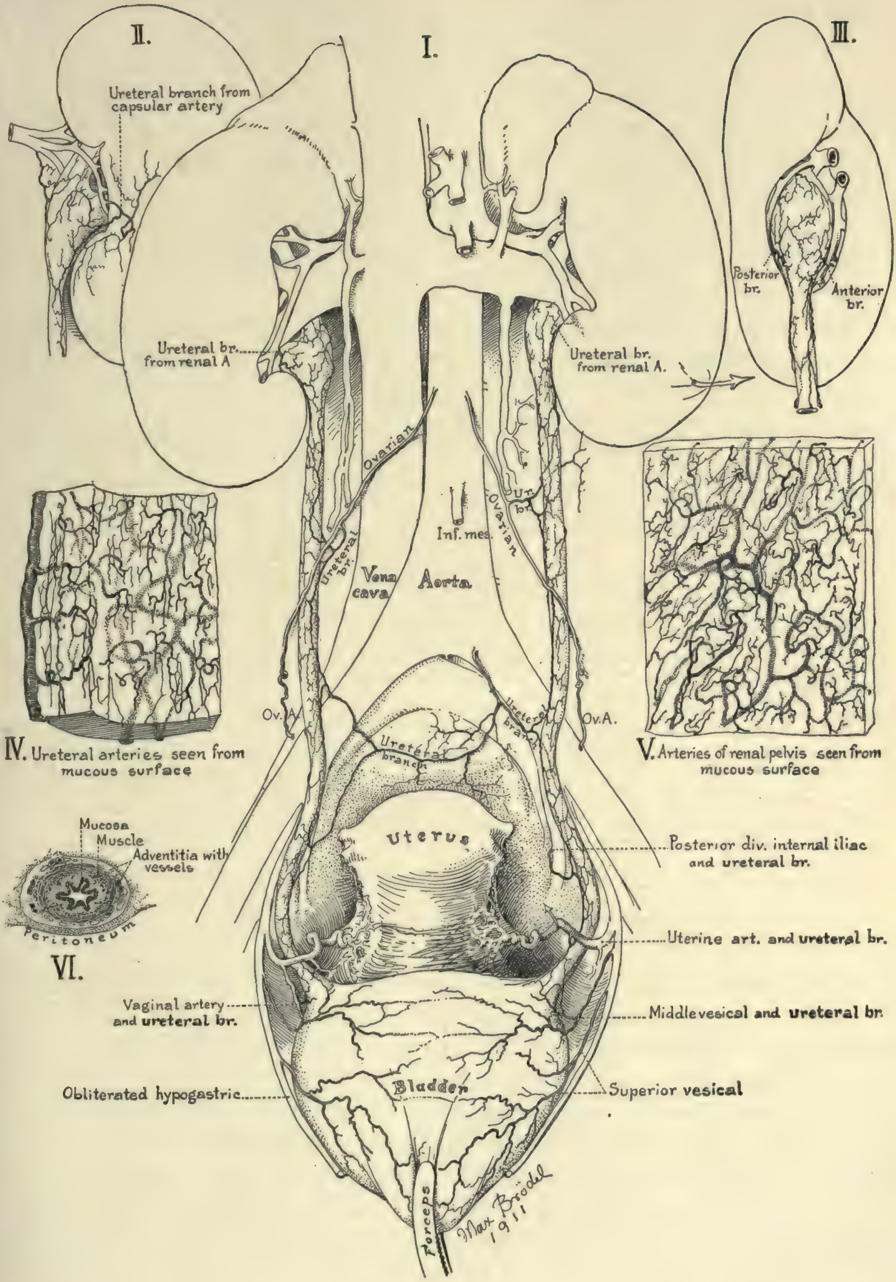
Fig. 107.—Arterial Circulation of the Ureter, × ½. I. Front view of the urinary tract, the bladder drawn downward and forward in order to expose both ureters down to their vesical orifices. The upper ureteral arteries are derived from the renal arteries. (See also II and III.)

The next branches come from the ovarian arteries and supply the abdominal spindle. Further down a ureteral branch arises from the aorta at its bifurcation. This branch is subject to many variations; it may arise higher up or there may be two separate arteries coming from the aorta or common iliac. The next branches below, supplying the pelvic spindle, are derived from the internal iliac or one of its divisions. Further down small tributaries are seen coming from the uterine, vaginal, and middle vesical, occasionally from the inferior vesical arteries. Most of these ureteral branches give off little twigs to the surrounding fat and peritoneum. In the outer coat the ureteral branches form a plexus, the larger vessels of which are very tortuous. These run parallel with the long axis of the ureter and anastomose freely, making it possible to inject the entire ureter from any of its arteries.

IV shows the arterial circulation of the ureter seen from the mucous surface, five times magnified.

V represents the arterial circulation of the renal pelvis seen from within, three times magnified.

VI is a transverse section of the ureter showing the relation of the vascularization to the individual coats, twice natural size.


I.
II.
III.
Ureteral branch from capsular artery
Ureteral br. from renal A
Ureteral br. from renal A.
Posterior br.
Anterior br.
Ovarian
Ovarian
Ureteral br.
Ur. br.
Inf. mes.
Vena cava
Aorta
Ov. A.
Ov. A.
Ureteral branch
Ureteral branch
Uterus
Posterior div. internal iliac and ureteral br.
Uterine art. and ureteral br.
Middle vesical and ureteral br.
Vaginal artery and ureteral br.
Obliterated hypogastric
Bladder
Superior vesical
Forceps
IV. Ureteral arteries seen from mucous surface
V. Arteries of renal pelvis seen from mucous surface
Mucosa
Muscle
Adventitia with vessels
Peritoneum
VI.
Max Brödel 1911

CHAPTER V.

PHYSIOLOGY OF THE URINARY ORGANS.

Here the physiologist has the problem of investigating and making clear the functions which result in removal of the urine from the blood and its discharge from the body. These two distinct processes, termed secretion and excretion, are, so far as is known to-day, the only functions of the kidney and other urinary organs. Secretion is a complicated, vital process in which many physical and chemical factors play parts. The kidney alone of the urinary organs is concerned with this function. The removal of the secreted urine is a mechanical process in which all the organs have a part. As will be shown, the organs of excretion are peculiarly adapted to meet the needs of animals, in that the constantly secreted urine is accumulated in reservoirs, the principal one being the urinary bladder, and discharged at convenient times and under the influence of the will.

Simplicity in exposition and clearness in conception are both best obtained by taking up separately the physiological functions of each individual organ composing the system. We will begin with the kidney, and, in succession, consider the ureter, the urinary bladder, and the urethra.

PHYSIOLOGY OF THE KIDNEY.

Parts of the kidney, notably the renal pelvis and its calices, are sections of the excretory system. The essential function of the kidney is, however, the removal of the substances which compose urine from the blood. In this function the kidney can be properly described as a secretory gland. It must be borne in mind that it differs materially from all other secretory glands in the body by reason of the fact that the substance secreted by the urine is not elaborated from substances in the blood, but presents, in different concentration, it is true, the same substances that occur in the blood. Contrary to a synthetizing gland, it is fair to look upon the kidney as a kind of specialized filter, and it is frequently viewed in just this way.

INTERNAL SECRETION.

The discovery of the ductless internal secretory glands and of the fact that many glands with an external secretion also possess internal secretion has led to attempts to establish the existence of such a function in the kidney. Brown-Séquard (*Arch. d. physiol. norm. et path.*, 1893, 5th series, 200), the first to propound this view, thought it established by his experiments in removing both kidneys and comparing the time of death with that caused by tying the two ureters in dogs, and by injecting emulsions of kidney into nephrectomized animals, and, as he thought, prolonging their lives. Knowing as we do now the complicated metabolic changes due to removal of organs, little value in the way of conclusive evidence of internal renal secretion would be deduced from Séquard's experiments. As a matter of fact, the very experiments themselves have not been confirmable. Other investigators find that dogs die just as soon when both ureters are tied as when both kidneys are removed, and injections of kidney emulsion shorten rather than prolong the lives of nephrectomized animals.

General Considerations.—Viewing the blood as the raw material to be operated on, the kidney as the machine and machinist combined, and the urine as the finished product, it would seem the physiologist could readily investigate and clearly present to the world the function of the kidney, but, even viewing the matter in this way, it must be confessed at the outset that the matter is neither easily investigable nor simple of explanation. So much depends upon chemical and physical principles, so little is known of either the physical or chemical constitution of the blood, and existing methods are so crude, that data of vital importance cannot be obtained. Every day some new discovery in the underlying sciences brings with it a flood of new knowledge in our own subject. The urine is readily obtainable and is readily subjectable to both physical and chemical studies. Many of these have been made, and a large part of our knowledge of renal physiology rests upon careful studies of this kind.

We have hinted, if not explicitly stated, that physical and chemical principles are involved in the secretion of the urine. For many years men have speculated as to the nature of these processes. Some of them are known today, others are still obscure. We cannot enter into even the briefest consideration of the war among theorists which is being waged along the entire line of biology. In the one camp are those who would explain all vital phenomena on chemical and physical grounds, while admitting that up to the present our knowledge of chemistry and physics has not sufficiently advanced to give

the necessary data; in the other camp are those who would ascribe vital activity to a vital function which they do not understand and which is entirely different from any known physical or chemical activity. It is usual in considering renal physiology to present three theories of secretion in which all others take their origin. We do not feel disposed to depart from this custom, because most of the experimental work elucidating the subject has been stimulated and suggested by these hypotheses, and they furthermore show the reader the direction of our views in regard to the secretion of the urine.

Bowman's Theory.—Bowman (*Phil. Tr. Lond.,* 1842, i, 57), the pioneer in this field, based his theory on deductions made from the study of the gross and microscopical anatomy of the kidney. He noted the difference of appearance between the Malpighian bodies and the tubules, and was the first to contribute exact and correct knowledge in regard to the finer anatomy of these structures. The arrangement of the glomeruli suggested an apparatus for filtration; on the other hand, to Bowman the convoluted tubules presented a marked similarity in appearance to the tubules of other secretory organs. Every subsequent observer has been similarly impressed. Bowman held that by a simple process of filtration under hydrostatic pressure the water of the urine passed into the tubule through the glomerulus, and the solid salts of the urine were added by the secretory activity of the cells of the convoluted tubules.

Ludwig's Theory.—Ludwig ("Handwörterbuch," Wagner, 1844, ii, 637), amplifying as well as corroborating the anatomical studies of Bowman, carried out in addition a number of experimental studies on animals in which he showed the effect of blood pressure upon the amount and character of urine secreted in given intervals of time. As a result of investigation, he reëmphasized the fact that the glomerulus was a perfect apparatus for filtration and the amount of filtration was dependent on the blood pressure. The greater the pressure the greater the filtration. Below a certain pressure, he found filtration ceased. To explain the different concentration of the salts of the urine as compared to their concentration in the blood, he assumed that the glomerular filtrate contains all the substances in the blood except the albumins, and that this dilute filtrate is rendered more concentrated by an absorption of water from it as the glomerular urine pours through the tubules.

Heidenhain's Theory.—Heidenhain ("Handb. d. Physiol.," Hermann, 1883, v, 637) repeated Bowman's work, but added new and different studies. In the first place, he studied the finer anatomy of the kidney by means of dyes, particularly indigo-carmin. He found this substance in the convoluted tubules, but never in the glomeruli, after it had been injected hypodermically

into animals, which were then killed and their kidneys studied at once. Furthermore, he studied the kidneys by means of the onkometer of Cohnheim and Roy (*Arch. f. path. Anat.*, etc., Virchow, 1883, xcii, 424), making comparisons of the circulation in the kidneys and of the urine secreted. As a result, he concluded that it is not the blood pressure, but the amount of flow through the kidney, which determines the rate of secretion of the urine, that the water, as Bowman believed, did come by way of the glomerulus, but by a true secretory process, and not mere filtration, and all the solid substances of the urine were added to the water by the secretory activity of the tubules.

For years most physiologists followed the view expressed by Heidenhain. Gradually, with innumerable experimental facts bearing upon the subject, it became recognized that these various views might each express a part of the truth as to what actually does occur. At the conclusion of this chapter we will attempt to sum up the salient facts known in regard to the secretion of urine. Just now we give in order such of the principal facts as regard the anatomy of the kidney, the chemical and physical constitution of blood in relation to kidney activity, and the chemical and physical characteristics of the urine, which directly bear on the elucidation of the physiologic function of the organ.

GROSS ANATOMY OF THE KIDNEY.

For the details of the gross and histological structure of the kidney the reader is referred to the chapter on Anatomy (IV); here we recall, to refresh the memory, and free from non-essentials, such facts as have a direct bearing on the physiologic problem at hand.

The kidney is a compound tubular gland composed of a great number of separate units. To begin with, the adult human kidney, presenting the appearance of a single organ, is made up of a number of separate parts, each quite distinct. Each section represents an original primary lobe (see Chapter III, p. 108). In many of the lower animals the original lobes are separated by distinct markings on the surface of the kidney. Such lobulated kidneys are often met with in the human being (Fig. 77).

It is possible to take the individual renal pyramid and its calyx as the unit of kidney function, but this is not sufficient, for when we analyze the pyramid it is evident that it is composed of a number of similar units, each representing in its way a complete kidney so far as function is concerned. At the apex of the pyramid about 20 collecting tubules empty; to each collecting tubule are connected many systems of glomeruli, convoluted tubules, loops of Henle, and connecting tubules. The arrangement is accurately represented in Figure 101.

Unless the connecting tubule has a secretory function (as will be shown, it probably has to do with the reabsorption of both water and solids from the urine secreted above), it becomes apparent that the tubule above it is the miniature kidney and qualitatively carries on the entire complicated function. Not merely the epithelial tubule, but the associated lymph vessels and nerves, and, above all, blood vessels, must be considered in viewing the essential anatomy.

The Malpighian Body.—This interesting structure which has led to so much speculation consists of two portions, the epithelial, dilated end of the tubule, "Bowman's capsule," and the glomerular network of capillaries which is intimately connected with one side of it (Fig. 102).

Bowman's capsule is composed of a single layer of flattened epithelium resembling endothelium. The glomerulus consists of capillaries lined by a single layer of protoplasm resembling syncitial tissue. The blood which comes to these capillaries is brought by a single vessel, the vas afferens, and after passing through the system is again re-collected into a single vessel, the vas efferens. Ludwig was the first to show that the latter vessel is of smaller caliber than the former, a fact since frequently substantiated. This arrangement would seem to be an ideal one to favor filtration. The vas efferens on leaving the glomerulus breaks up into a second group of capillaries which surround the convoluted tubules. Bowman applied the name "Great Blood Reservoir of the Kidney" to this second group of blood vessels.

The arrangement of the capillaries in the human glomerulus differs from that in the dog, which is usually pictured in anatomies. In the former, it is possible, as shown in Figure 102, for the blood to circulate in only a part of the capillaries. In the dog it must pass through them all.

The Convoluted Tubule.—As Bowman's capsule passes over into the convoluted tubule, the flat epithelium becomes cubical and then still higher until the typical columnar type is attained (Fig. 102). Disse ("Handb. d. Anat. d. Menschen," 1902, vii, part 1) notes the two types of epithelium met with in the convoluted tubule and the resultant change in the appearance of the tubule itself. When the epithelium is high columnar, the lumen is narrow; when it is cubical, the lumen is wide. Under ordinary conditions most tubules are wide-lumened. In animals deprived of water the kidneys show a mixture of wide-lumened and narrow-lumened tubules. In hibernating animals during the winter-sleep all the tubules are narrow-lumened. The conclusion drawn from these appearances is that in functional activity the tubules have lower cells and wider lumina; furthermore, that the different tubules act entirely

independently of each other. This independent action is even more plainly shown in the studies of kidneys in which indigo-carmin is being secreted.

The epithelium is in a single layer set on a basement membrane of extreme thinness, composed of fibrils continuous with the general fibrous framework of the kidney. The cell nucleus is situated near the base of the cell. The protoplasm of the cell shows an arrangement of granules in lines perpendicular to the basement membrane. On the lumen end of the cell there may be a ciliated appearance. The boundaries between cells are often difficult to determine. In studying the finer anatomy of the renal epithelium, perfectly fresh specimens must be obtained and very delicate staining methods employed. In no part of the body do post-mortem changes set in earlier or lead to more marked changes in anatomical appearance.

The Loop of Henle.—The convoluted tubule passes on into the descending loop of Henle (Fig. 103). The epithelium is entirely altered, the cells are cubical, often flattened, there is no granulation, the protoplasm is clear. The descending loop passes on to become the ascending loop. Here the cells once more become almost identical in appearance with those of the convoluted tubule, showing even greater tendency to undergo post-mortem degeneration, and no observer has ever been able to show that boundaries exist between the separate cells.

The Collecting Tubules.—The cells in this next part of the tubule are cubical, have clear protoplasm, with nuclei near their centers. Most observers state that there is no basement membrane, but the cells are set directly in the stroma of the kidney (Fig. 101).

Blood Vessels of the Tubular Part of the Kidney.—We have already spoken of the breaking up of the vas efferens into a second capillary system which surrounds the convoluted tubule. The entire tubular system is surrounded by a network of innumerable capillaries and blood vessels. In proportion to its weight, no organ in the body, the lung possibly excepted, is more richly supplied with blood (Fig. 101).

Comparative anatomy shows the vascularization in the medullary portion of the kidney to be much less in animals which live in water—such as fish—than in animals which live on dry land. Furthermore, the tubular system in the water animal, so far as the medullary part is concerned, is much shorter than in the land animal. This has been used as evidence in favor of the fact that there is a reabsorption of water in the medullary section of the tubule, it being argued that in the land animal the long tubule and the rich vascularization permit the reabsorption of water and its consequent conservation. In the animal whose element is water no such conservation is necessary.

The Lymph Vessels.—The kidney is richly supplied with lymph vessels which ramify in every part of the organ. Most of them unite and pass out of the kidney in the columns of Bertin. In the hilum they are united into several large trunks running to lymph glands in the neighborhood. Some of the lymph vessels pass out through the fibrous capsule of the kidney.

Nerves of the Kidney.—The kidney is richly supplied with nerves which run to every part of the organ. The large nerve trunks accompany the blood vessels in the hilum. On entering the substance of the organs, these nerves break up into finer filaments which end in the blood vessel walls and also in the walls of the epithelial tubular system all the way from the glomerulus to the papilla. The tiny nerves which run to the epithelium often pass in between the individual cells. There are distinct nerve endings similar to those which have been described in the salivary glands and which are termed secretory nerve endings. The nerves which go to the blood vessels are of both the vaso-constrictor and the vaso-dilator variety. It has been found impossible to determine the function of the nerves to the epithelial tubules by stimulation such as used to demonstrate their action in the salivary glands because they are carried in the same trunks with the vaso-motor nerves, and these latter, as will be shown, have such an important bearing in determining the amount of blood which can flow to the kidney, and consequently its functional activity. What is known is that the kidney can be completely severed from all nervous influence and continue to secrete urine in as large amounts as under normal conditions. This is evident in experiments destroying all the nerves to the kidney. That such destruction can be made complete is no longer to be questioned, since transplantation of the organ without destruction of its function can be carried out. Those desiring accurate information in regard to the nerve endings in the kidney should study the splendid paper of A. E. von Smirnow (*Anat. Anz.,* 1901, xix, 347-359).

J. Rose Bradford (*J. Physiol.,* 1889, x, 358) was the first to demonstrate that the vaso-dilator as well as vaso-constrictor nerves of the kidney are connected to the spinal cord by the ventral roots of the last six dorsal and first two lumbar nerves. Most of the fibers are in the last few dorsal ones. His investigations were carried out on dogs. Each species of animal seems to show variations in distribution. The exact distribution in the human being is not known. Bradford has shown that, after leaving the spinal cord by the ventral root, the nerves reach the kidney through the splanchnic nerves, major and minor, which pass to a plexus behind the adrenal glands. From this plexus a number of large trunks pass to the kidney.

HISTOLOGICAL STUDIES OF THE KIDNEY UNDER VARIOUS EXPERIMENTAL CONDITIONS.

The originator of this very productive line of investigation was R. Heidenhain, who first examined the kidneys of an animal after giving intravenous injections of a dye. The advantage of a dye over other substances is that it can be easily seen and needs no chemical test to demonstrate its presence. Heidenhain employed indigo-carmin and noted that after the intravenous injection of this dye the entire body would show some blueing, but the color was very intense in the kidneys. Microscopical examination of such a kidney showed no color in the glomeruli, granules of the stain in the lumen of the tubular system below the glomerulus, and a blue granulation in the cells of the convoluted tubules and the ascending loops of Henle. The tubules, however, were not equally stained; the indigo filled some, but was entirely absent in others. Between these two extremes every variation as to amount was met with. From these findings Heidenhain deduced that the individual tubules acted independently of each other and that the dye was secreted by the cells of the convoluted tubules and the ascending loop of Henle. These results have been repeated in countless experiments, and it cannot be questioned that dyes in general introduced into the body are secreted into the urine through the convoluted tubules.

Pfeffer and Overton have shown that indigo-carmin in the cell of the convoluted tubule is in an altered state from what it originally was in the blood and has a different color. In the urine it has returned to its original state. This is further evidence of a real secretory activity of the epithelial cell. In the so-called vital staining, these authors have noted the same distribution of the coloring matter; furthermore, they observe that the stains are not equally distributed through the protoplasm, but are limited to the granules. It is of interest that, with vital stains, such as methylene blue, pieces of kidney immersed in it after removal of the organ show the same type of coloring. This has been adduced as an argument against specific secretion. It is, however, untenable, because substances like indigo-carmin, which are not vital stains, do not act in removed pieces of kidney as they do when injected into the blood of a living animal.

Evidence has been brought to show that the granules or vacuoles of the cells lining the convoluted tubules are structures of great importance in relation to the function of the tubules. The originator of this conception, Gurwitsch (*Arch. f. d. ges. Physiol.*, Pflüger, 1902, xci, 71), noted in the kidneys of frogs fed on toluidin blue that there was a beautiful staining of the

granules of the cells and that the color was quite different from that of the original dye. He described in the frog's kidney in the cells of the convoluted tubule three entirely different kinds of granules: first, large granules, which stained black with osmic acid; second, small and very numerous granules precipitated but not stained by osmic acid, also precipitated by bichlorid of mercury; third, large granules which neither stained black nor coagulated with osmic acid. The first type of granule is evidently a fat-containing body, the second a proteid body, and the third, according to Gurwitsch, a vacuole filled with water, containing the salts of the urine in solution. He considers these vacuoles and granules to be a kind of especial apparatus permitting the taking up of substances from the blood and the distribution of the same into the urine. Hoeber and Königsberg (*Arch. f. d. ges. Physiol.,* Pflüger, 1905, cviii, 323) demonstrated in frogs which had been given vital stains that colored granules such as those observed in the cells of the convoluted tubule can be found in the urine. This has never been accomplished in man.

Courmont and André (*J. de physiol. et pathol. génér.,* 1905, vii, 255) have demonstrated that uric acid is passed through the kidney in exactly the same way as the vital stains and indigo-carmin.

From the time of Heidenhain's original experiments, there have been those who suggested that coloring matter was really in very dilute form excreted through the glomerulus, and that the presence of masses in the convoluted tubules and of the dye in the epithelial cells was due to a reabsorption of water and dye. In the frog the blood supply to the convoluted tubule and the glomerulus is from two distinct vessels. Gurwitsch, ligating the vessel which supplies the canals, found the kidney secreted but little less urine than its fellow, but the indigo-carmin given hypodermically was practically not secreted at all. This demonstration, in spite of the objections of Adami, seems to us conclusive evidence that the blue in these cells is taken from the blood and not from the urine. The reverse of this experiment, where the vessel supplying the glomeruli is tied, and then indigo-carmin given, is equally interesting. In a frog so treated the urine on the operated side falls almost to nothing, but a microscopical examination of the kidney shows the cells of the convoluted tubules packed with the coloring matter.

The histological anatomy of the kidney affords no evidence as to how the salts in normal urine, urea, sodium chlorid, etc., are secreted. It is solely by inference that Heidenhain thought they came through the convoluted tubules in a similar way to indigo-carmin. But, under the circumstances, we are not justified in drawing so large an inference without more direct proof.

THE CHEMICAL AND PHYSICAL CONSTITUTION OF THE BLOOD AND ITS BEARING ON RENAL SECRETION.

We know that the blood pressure, the rapidity of blood flow through the kidney, the amount of water and of the various urinary salts which occur in the blood, all have a most important bearing on the amount of urine secreted and on its character. Let us consider briefly some of these factors.

Influence of Blood Pressure.—Ludwig and his pupil, Goll, showed by a number of interesting experiments that the amount of urine varied under many conditions with the blood pressure, in the sense that the greater the pressure the greater the flow of urine. When the blood pressure fell in the aorta below 40 mm. of mercury, urine ceased to be secreted at all. They obtained increased blood pressure in various ways; e. g., tying of a number of large peripheral arteries, giving of digitalis, stimulation of the heart by exercise, etc. In the opposite direction lowering of the blood pressure was obtained by stimulation of the vagus nerve in the neck, cutting the spinal cord, narrowing the renal artery mechanically, etc. Several essential factors not recognized by Ludwig are now well known to have bearing here; nevertheless, it is true that, other conditions being equal, the amount of secretion of urine from the kidney is proportional to the blood pressure. The facts which have developed since are that the blood pressure in the renal artery may not be the same as that in the carotids. One cannot, by getting the general blood pressure, determine the pressure in the renal vessels. When the blood from the artery of one animal is transfused directly into the vein of another, the blood pressure, as Magnus has shown, may be enormously increased and yet the amount of urine remain stationary, or even fall. This is no conclusive evidence against the influence of blood pressure. The nature of the blood by the transfusion is entirely altered, water is squeezed out and replaced by formed elements, thus rendering the blood thick and unsuitable for filtration. The same objection is to be made to Heidenhain's experiment of increasing the blood pressure in the kidney by pressing on the renal vein. This leads to a deposit of cells on the glomerular filter which would prevent filtration, and, as a matter of fact, the secretion of urine does stop during this experiment. If, however, as Tammann and Robert (*Ztschr. f. physikal. Chemie,* 1896, xx, 180) have shown on the kidneys of oxen removed from the body, the circulating fluid be water, then obstruction in the renal vein is followed by increased flow of urine. Under the conditions of this experiment, the character of the filter could not be influenced by the filtrate.

Relationship between the Amount of Blood Flowing through the Kidney and the Amount of Urine Secreted.—All the evidence at hand—and there is a great deal of it—goes to show that the greater the amount of flow through the kidney the greater the amount of urine secreted. Heidenhain first brought this to view and held it as evidence that the water in the urine is truly secreted and not merely mechanically filtered.

Most of the studies of this kind have been made by means of the Roy-Cohnheim onkometer. This is a metal instrument, the two halves of which can be opened. It is essentially, when closed, a flattened, hollow ball. There is a place for the exit of the vessels of the kidney. It is lined by thin membrane, usually calf's peritoneum. Between the membrane and the kidney is a pool of warm oil. This oil is connected with an upright tube. When the kidney is placed in this instrument, variations in size are noted by the changes in the level of the oil in the tube. By this instrument the slightest variations in the size of the kidney can be determined. Care must always be taken to see that there is no compression on the renal veins, else the swelling of the kidney may not be due to increased flow of blood. In general, with increase in size of the kidney, there is increase in blood flow, and, with decrease in the size of the kidney, decrease in blood flow. Under certain conditions there are some exceptions. As we have already noted, the blood may become more viscid and circulate with more difficulty; this would lead to increased size of kidney, but not increased diuresis. Certain drugs, notably caffein, seem to render the blood more fluid. There may be a diuresis from caffein and yet no increase in the size of the kidney. Examination of the renal vein shows, however, that the blood is much more arterial than normal, a condition which evidences increased circulation.

How Much Blood Actually Passes Through the Kidney.—According to Heidenhain, there are three circulations of a given portion of the blood in every minute. He estimates that a man weighing 75 kg. should have approximately 6 kg. of blood. On this basis, in 24 hours there would flow approximately 24,000 l. Estimating weight of a kidney as 1/200th of the body, the amount of blood passing through both kidneys in a day would be 122.5 l. This estimation, as pointed out repeatedly, is too small, because the kidney is a very vascular organ. Tigerstedt ("Lehrbuch der Physiologie des Kreislaufes," Leipzig, 1893), who actually measured the flow in the renal artery of the dog, then compared the caliber of the dog's artery to that of man, and, as a result, estimates that in the average man under normal conditions the flow of blood to the two kidneys would amount to 460 l. Barcroft and Brodie (*J. Physiol.*, 1905, xxxii, 18) estimate that the amount varies between

311 and 590 l. per day. Heidenhain pointed out that, if one takes account of the average amount of urea in the blood, and then attempts by the theory of Ludwig to explain the presence of 30 gr. of urea in 2 l. of urine, it is necessary to assume that 60 l. of fluid passed through the glomerulus and that 58 are reabsorbed. As noted, Heidenhain's figures are incorrect, and we do know that by induced polyuria the amount of urine can be brought to 14 or 15 l. a day; nevertheless, his objection still bears a great deal of weight. It seems very unlikely that such an enormous reabsorption occurs, or that so much of the fluid of the blood could be expressed.

Starling has set up three propositions as criteria for testing the view of Ludwig that the glomerular filtrate is simply blood serum minus albumin: the first is that the urine with increased production should approach nearer and nearer to the character of the blood serum. The second, that the amount of urine must increase and diminish in like proportion to the amount of blood flowing through the kidney. The third, that with increased diuresis the absolute amounts of the salts in the urine in a given interval of time should be increased.

Character of the Urine During Polyuria.—It is a fact that the greater the polyuria the nearer the urine approaches the blood serum less the albumin in physical and chemical constitution. When large amounts of urine are secreted, the reaction changes from acid to faint alkaline. The freezing point of the two may become practically identical. In animals, this can be secured by first injuring the tubular system with corrosive sublimate and then causing a diuresis by means of salt infusion directly into a vein.

Relationship Between Blood Flowing Through the Kidney and the Amount of Urine.—We have already stated that these two factors do vary in the same way and here call attention to certain experiments in which infusions have been used to induce polyuria, also to mention the effect of certain drugs in the same direction.

Hydræmia and Polyuria.—That plethora, produced by transfusing the blood of one animal into another, is followed by a fall in the amount of urine we have already stated. The reverse of plethora, hydræmia, should be followed by polyuria, as the substance to be filtered is more fluid. As a matter of fact, hemoglobin examinations show that in an intravenous injection of saline solution or of glucose solution the blood becomes more watery. In addition, however, onkometer studies demonstrate that diuresis is, in part, at least, due to a marked dilatation of the renal vessels, and great increase in blood flow through them. If, while the salt solution is being introduced into a vein, enough blood is let out of an artery to keep the kidney at the same volume in the onkometer, there is no increased diuresis. This interesting observation was

first made by Starling. In place of bleeding, the same result can be obtained by direct pressure upon the renal artery.

Mention has been made of the action of caffein and theobromin, which, in combination with salt solution, caused an increased diuresis without any enlargement in the volume of the kidney. We have noted that there is, however, apparently increased flow through the kidneys. Digitalis, which increases the general blood pressure, actually decreases the size of the kidney, and yet there is increased diuresis. The cause here is probably similar to that in the case of caffein. We will point out presently how the increased diuresis may be explained after the use of these drugs in an entirely different way.

With Polyuria, Is There an Increase in the Amount of Solids in the Urine in a Given Unit of Time?—There is no question that up to a certain point there is a marked increase in the solids of the urine during diuresis. This lasts only while the substances are still present in the blood. Unless it is constantly added, as by saline infusion, after a few hours of diuresis the amount of sodium chlorid excreted in a given unit of time is much less than before the diuresis, and it can fall almost to *nil.* If the percentage of sodium chlorid and urea in the blood be kept up to normal by constant additions of these substances, the amounts excreted will be considerably greater than when polyuria is not present. We have frequently seen in a polyuria induced by drinking Apollinaris water the amount of urea as well as sodium chlorid increased in a fifteen-minute interval of three or four times the amount observed in fifteen minutes before causing the polyuria. Loewi (*Arch. f. exper. Path. u. Pharmakol.,* 1905, liii, 15-49) has pointed out that the estimation of the increase in output of these salts during polyuria is made difficult not only by the fact that their amounts in the circulating blood may vary, but also because different salts have different coefficients of reabsorption in the convoluted tubules.

The amounts of indigo-carmin, and phenolsulphonephthalein secreted in two or three hours are not influenced by polyuria in the least. Rosks and Katsuyama (*Ztschr. f. physiol. Chem.,* 1899, xxviii, 587) have pointed out that the amount of phosphates in the urine is not increased by polyuria. It is known that the phosphoric acid in the circulating blood is in some albuminous combination. Loewi confirms this in his experiments on animals, and we have seen the same phenomenon in a few of our patients where we have induced polyuria to test the function of the kidney.

While water alone will cause a diuresis, water and caffein will produce more marked results still. Theocin gives greater results than caffein. Dreser (*Ztschr. f. Biol.,* 1885, xxi, 41) first showed that in a polyuria induced by

this drug the total number of molecules of solid substance secreted in a given unit of time, as measured by the quantity of urine times the reduction of the freezing point, was greatly increased. He attributed this to a stimulation of the secretory power of the renal epithelium, a view pretty generally given up now. Our conclusion in regard to the excretion of grape sugar must exactly correspond to the view expressed in regard to the dyes and the phosphates. This substance exists in the blood normally in some albuminous combination, in a percentage which varies between 1 and 1.5. Above the latter figure, if grape sugar is present, it is in free solution just like the sodium chlorid. This excess of free grape sugar responds to polyuria exactly as urea and sodium chlorid does. On the other hand, if a glycosuria be due to phloridzin, the induction of polyuria has not the slightest influence in increasing the amount of sugar excreted. The phloridzin gives the renal epithelium the power to take sugar out of its albuminous combination in the blood. This albuminous sugar acts like the dyes and the phosphates. One can, by giving an excess of phosphates, make them act like the saline and sugar infusions.

Facts Indicating a Reabsorption of the Glomerular Filtrate in the Tubular System of the Kidney.—We have already pointed out in connection with the anatomical considerations that certain facts of comparative anatomy strongly indicate a reabsorption of the water which has passed the glomerulus in the tubules, and especially the tubules of the medulla.

Ribbert (*Arch. f. path. Anat.*, etc., Virchow, 1883, xciii, 169) thought that such a reabsorption was indicated by his findings in kidneys undergoing parenchymatous nephritis. On inducing nephritis in animals experimentally, and taking pieces of the fresh kidney and putting in boiling water and then subjecting to microscopical examination, he found no coagulation of albumin in the glomeruli, but distinct casts in the tubules. Furthermore, the more distant the tubular section from the glomerulus the denser the albuminous coagulation. It is generally agreed that the albumin in the urine of nephritics comes through the glomeruli. Bearing this in mind, it is difficult to interpret Ribbert's findings differently from that of a reabsorption.

The polyuria met with in chronic interstitial nephritis suggests this disease has interfered with the reabsorptive capacity of the tubules, as in marked cases it is impossible to secure a urine of high specific gravity by giving much solid food and depriving the patient of all water.

The experiments of H. Meyer ("Über Diurese Sitzungber. d. Gesellsch. z. Beförd d. ges. Naturw.," Marburg, 1902-1903, 92-95) on patients suffering with diabetes insipidus are difficult to interpret in any other light than that this disease is essentially one in which the reabsorptive power of the tubular

system has been destroyed. The cases studied by Meyer were patients suffering with diseases of the brain, which reminds us that Claude Bernard and Eckhardt long ago demonstrated in animals that by injuring certain portions of the brain permanent polyurias could be established. Anatomical studies have shown the kidneys in diabetes insipidus to present no visible changes from the normal. It would seem, therefore, that through nervous influence a kidney can be made to lose its capacity to reabsorb water. Perhaps the so-called secretory nerves have some such function. The characteristic of urine in diabetes insipidus is that it is normal both as to microscopical and chemical findings, but that it is very dilute. A patient may pass as much as 12 l. a day, and, if deprived of water, while the amount drops to normal, the dilution remains the same and the patient suffers intensely. Generally on sufficient fluid these patients seem as healthy as any other individuals. Meyer noted that on giving patients with diabetes insipidus theosin not only is there no reabsorption of water, but the total amount of sodium chlorid is also greatly increased. As the amount of polyuria with or without the theosin is identical, the explanation of the drug's action can only be that it prevents the reabsorption of sodium chlorid which normally takes place. In these cases there was no change in the phosphorus or uric acid outputs after giving theosin.

The reabsorption of water would seem to be fully demonstrated, in addition to the above-mentioned experiments, by many others. Equally conclusive evidence is at hand that certain of the solids are likewise reabsorbed. The ordinary polyuria experiments show that urea, sodium chlorid, and excesses of sugar are excreted by the glomeruli and can be increased by increasing the glomerular filtrate, and that the phosphates, uric acid, and the dyes are not increased by causing polyuria. Experiments with other salines than sodium chlorid indicate that these two are passed in the glomerular filtrate. Their coefficients of excretion differ each from the other, and, as Loewi has shown, the excretion coefficient is not dependent on the power of disassociation of the salt. For example, sodium iodid is not excreted like sodium chlorid, although it is fully as diffusible in solutions of water. Polyurias in animals have been experimentally induced by giving intravenous injections of various salts alone and in combinations and the relative outputs of the different constituents in the urine determined. The most extensive and illuminating of these experiments are those of Cushny and Loewi (*J. Physiol.,* 1901-2, xxvii, 429). The reader is referred for the details of these experiments to original sources; here we content ourselves with a few pertinent examples.

If equal parts of isotonic sodium chlorid and sodium sulphate solutions

be injected directly into the veins of an animal a diuresis will start and continue for several hours. If the urine be examined at fifteen-minute intervals it will be noted that the height of polyuria and sodium chlorid excretion correspond. On the other hand, the sulphate excretion is much slower and may reach its maximum only as the polyuria ceases. Mixtures of sodium chlorid and urea show similar results, with the exception that the urea is nearer to sodium chlorid than is sodium sulphate. The amount of urea and of sodium sulphate present in the blood has a great deal to do with the amounts of these substances excreted. When the blood contains much more sodium chlorid than sodium sulphate there may be, nevertheless, much less of the chlorid excreted. This shows that the concentration of the salts in the blood is not the determining factor of their excretion in the urine. Loewi further showed that he could bring on a diuresis by injecting solutions of disodium phosphate, sodium chlorid and glucose. When this diuresis ceased, a second one could be induced by giving caffein or theosin, and finally a third one by giving potassium nitrate. After the theosin it was observed that the sodium chlorid was excreted exactly like the sodium sulphate. Loewi likewise showed that sodium iodid, a very diffusible salt, acts exactly like sodium sulphate, which would indicate that, if a reabsorption in the tubular system does occur, it is due to some specific process not known and certainly not a simple osmosis. The interpretation of these results is that urea, sodium chlorid, and all the free salts pass in the glomerular filtrate, but, while sodium chlorid is reabsorbed, the other salts are not reabsorbed at all. It is difficult to determine whether there is any reabsorption of urea in cases of this kind. The sodium chlorid is a necessary substance for life, and the kidney conserves enough to protect the body. When animals are kept for a long time on salt-free diet, the total sodium chlorid of the body is greatly reduced, and, although it is present in the circulating blood, none is secreted in the urine. On the other hand, a foreign salt is excreted entirely.

Innumerable investigations which are based on preventing the outflow of urine from the ureter or allowing it under conditions of pressure have been carried out in an endeavor to prove a reabsorption of water and solids. Followers of the original Heidenhain theory have objected to a reabsorption interpretation on the grounds that the pressure in the ureter caused an injury to the kidney and incomplete secretory function.

Hermann found on ligating the ureter that the urine which collected in the pelvis contained more urea and less sodium chlorid than the urine from the opposite kidney. Other observers have found both markedly reduced. In experiments both in animals and in human beings, where pressure has been

brought into one ureter by means of a catheter connected with a manometer, it has been noted that the kidney under pressure secretes less fluid than its fellow; also that the amounts of solids are reduced, and especially the sodium chlorid. It is of interest, however, that a dye such as indigo-carmin is also almost entirely prevented from appearing in the urine. This certainly points to an interference with the functions of the convoluted tubule. Sobieransky pointed out years ago that if indigo-carmin and caffein be given at the same time no color shows in the cells of the convoluted tubules. He used this as evidence that the color usually found there is due to reabsorption of the blue from the urine. Possibly in addition to the secretion of indigo-carmin by the convoluted tubules there may be, under some circumstances, reabsorption. When the pressure in the ureter reaches a certain amount the secretion entirely ceases. Magnus and Gottlieb (*Arch. f. exper. Path. u. Pharmakol.,* 1901, xlv, 241), by giving intravenous injections of salt infusion and chloral hydrate, have succeeded in bringing the blood pressure to within 2 mm. of ureteral pressure before secretion entirely stopped. In this connection it is interesting to recall the work of Tammann (*Ztschr. f. physik. Chemie,* 1896, xx, 180), which is mainly now of historic interest. His experiment was based on the physical fact that to secure the pressure of water through a semi-permeable membrane out of a saline solution a pressure as great as the sum of all the osmotic pressures of the salts in solution was needed. In horse's blood the total osmotic pressure measured by the freezing point method is 5,840 mm. of Hg. five thousand of this is due to inorganic salts. Of the remainder the albumin caused 6; carbonic acid, 20; grape sugar, 50 to 100; urea, 30 to 180; creatin, 110 to 360. The pressure in the ureter is 60 mm., that in the glomerulus from 80 to 160 mm. The difference may be only 20 mm. Tammann, as a result, thinks the conclusion inevitable that the glomerular filtrate is not only water, but all the substances of the blood serum, except albumin.

Action of the Nervous System on the Secretion of the Urine.—The nervous system regulates to an extraordinary degree the secretion of the urine. The most obvious way in which it does this is by causing increased blood pressure through stronger action of the heart and increased flow of blood through the kidneys by vaso-dilator action. As pointed out, J. Rose Bradford has demonstrated in the dog that centers in the brain are directly connected with the vaso-motor fibers going to the kidney. It is the common experience that the amount of the urine will vary greatly with the nervous and psychical influences surrounding a healthy individual. Functional polyuria is the common observation of every physician making urological examination. Meyer has shown in the interesting disease, diabetes insipidus, that the central nervous system acts

in a way to suggest that the polyuria is due to an incapacity of the tubules to reabsorb water.

Reaction of the Urine.—Heidenhain thought that to obtain an acid urine from alkaline blood meant that there must be some vital activity of the cells, and that it was inexplicable on mere filtration hypothesis. It must be remembered, however, that the acidity of the urine is not due to free hydrogen ions, but to acid salts. When the alkalinity of the blood and the acidity of the urine are determined in reference to the free OH ions in one and H ions in the other, there is but little difference between the two. Koeppe ("Handbuch der Urologie," Frisch u. Zuckerkandl, Vol. I, p. 117) has shown that by mixing ammonium chlorid and magnesium sulphate a neutral solution is obtained, and on adding this to an alkaline solution of disodium phosphate an acid solution results. He points out that all these substances exist in the blood and passage through the kidney may be accompanied by some such chemical change. The acidity of the urine obtained by titration is largely due to the acid phosphates.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE URINE.

As already stated the product of the kidney activity is the urine, an aqueous solution of a number of salts normally present in the blood. Normal urine when first voided is clear and transparent, but varies in color from that of water to a dark beer. When urine stands in a cold place, even when protected from all contamination of bacteria, there is a slightly cloudy precipitate, originally thought to be mucin, but now considered albumin. In addition to this, in both acid and alkaline urine, there is a precipitation in many cases of salts in the form of amorphous or crystalline deposits. The amount of urine excreted in a day in patients on normal diet and the average amount of water varies from 800 to 1,200 c. c. It is said to be slightly less in women than men. It is absolutely less in children than in adults, but proportionally greater. If very little fluid is taken the amount of urine may sink below 500 c. c.; on the other hand, by drinking very large amounts of water it can be raised to 13 or 14 liters a day. Quincke has pointed out the greater secretion of urine during the day than at night, and especially notes the polyuria during the first hour after getting up in the morning.

The amount of urine secreted by each of two normal kidneys is approximately equal in the 24 hours, but varies greatly in short periods of from 5 to 20 minutes.

The specific gravity varies from 1.002 to 1.035 under normal conditions, and is inversely proportional to the quantity. Low specific gravities

are met with where much fluid is ingested, and high ones where much food and little fluid are taken into the stomach. On normal diet the specific gravity varies between 1.012 and 1.030.

The reaction of normal urine may be acid, amphoteric or alkaline, depending largely upon the character of food ingested. In meat-eaters it is acid; in vegetable-eaters it is alkaline. On a mixed diet the acidity is highest just before breakfast and lowest, if not actually alkaline, after each meal during the process of digestion. Starvation is always accompanied by acid urine; it is slightly increased by muscular exercise; various drugs can alter it. Decomposition from bacterial causes quickly renders it alkaline.

Not only the water but the solids in the urine vary greatly, depending on the size of the individual, the amount of exercise, the amount and character of the food, the condition of health. In individuals of the same weight and under exactly equal conditions of food intake and external surroundings the amounts vary markedly, not only in periods of 24 hours, but over days and weeks: the amount of coal necessary to run one engine does not suffice for the next, and is too much for the third.

At 15° C. the specific gravity of water is 1.000. Haeser has given a formula for approximately estimating the total solids in the urine. This is to deduct from the specific gravity of the urine the specific gravity of water and multiply the remainder by the constant 2.33. This gives in grams the amount of solids in 1 l. of urine. Otto Weiss states that in the average 24-hour urine there are 60 gms. of solid matter, of which 25 are inorganic and 35 organic salts.

Weiss's Table.

Inorganic Substances.	Organic Substances.
Sodium chlorid, 15 grams.	Urea, 30 grams.
Sulphuric acid, 2.5 grams.	Uric acid, 0.7 gram.
Phosphoric acid, 2.5 grams.	Creatinin, 1 gram.
Potassium oxid, 3.3 grams.	Hippuric acid, 0.7 gram.
Ammonia, 0.7 gram.	Other substances, 2.6 grams.
Magnesia, 0.5 gram.	
Calcium oxid, 0.3 gram.	
Remaining substances, 0.2 gram.	

Not only the total amount of these substances varies greatly, but also the relative proportions in health and disease; furthermore, in disease, and in unusual conditions, many substances appear not found in normal urine. I will consider in a little more detail the chemical characteristics of the urine in the chapter on Examination of the Urine.

In addition to the physical characteristics already mentioned, it is of interest to note the variations in its freezing point, since the method originally employed by Dreser (*Ztschr. f. Biol.,* 1885, xxi, 41) and made popular by Koranyi has found such a place in determining the functional activity of the kidney. Dreser noted that the freezing point of urine in health varied from minus 0.16 to minus 0.23 degree; under average conditions of fluid and liquid ingestion Koranyi puts the lowering of the 24-hour specimens normally between minus 1.3 and minus 2.2 degrees.

Just as the freezing point varies, so does the electric conductivity, in very wide margins. Neither the freezing point nor the electric conductivity is influenced by the presence of albumin, which makes them superior to mere taking of the specific gravity.

In the chapter on the Examination of the Urine are described various normal and pathological elements sometimes met with.

GENERAL CONCLUSIONS.

None of the theories proposed cover the entire question of secretion; parts of both Ludwig's and Heidenhain's hypotheses hold good. There is no real conflict between them.

Hydrostatic pressure undoubtedly plays an important part in the glomerular filtration.

Osmosis and diffusion, as ordinarily understood, cannot be a considerable factor in the process. This does not mean that ultimately simple physical principles may not explain secretion of urine.

The character of the urine will depend in large measure on the character of the blood.

The amount of urine is proportional to the amount of blood flowing through the kidneys. The glomerular filtrate may be a blood serum minus albumin, as originally suggested by Ludwig.

Uric acid, the phosphates, the dyes, sugar after giving phloridzin, are undoubtedly added to the urine by the secretory activity of the cells of the convoluted tubules and of the ascending loop of Henle. It is quite probable that urea is secreted in the same way; perhaps even sodium chlorid and water.

There is a reabsorption of water and sodium chlorid from the glomerular

filtrate by the tubules; probably all parts of the tubular system are concerned. In addition to the evidence already offered, we will recall the experiments of Ribbert and others, who found that, after destroying the medullary substance of one kidney and leaving its cortex intact, the amount of water, sodium chlorid, and, to a much less extent, urea excreted was greater than from its healthy fellow.

The vacuoles first described by Gurwitsch may be a special apparatus for carrying on the secretory activity of the cells of the convoluted tubules.

The reabsorption of substances seems to be a selected one depending on the needs of the body. Sodium chlorid and water are readily reabsorbed; foreign salts and the end products of normal metabolism but little absorbed.

The kidney possesses in common with some other organs the capacity to combine benzoic acid and glycocol into hippuric acid. This was first demonstrated by Bunge and Schmiedeberg (*Arch. f. exper. Path. u. Pharmakol.,* 1877, lx, 233), and can be produced in the living animal as well as in the excised kidney. This is the only known synthetizing power which the kidney possesses.

PHYSIOLOGY OF THE RENAL PELVIS AND URETER.

The kidney pelvis, physiologically considered to be the expanded upper part of the ureter, through its system of calices receives the urine from the collecting tubules, transmits it to the ureter, which in turn propels it toward the bladder. The two ureters do not act synchronously, but under ordinary conditions about equally. In Figure 105 is shown the spindling of the ureter; Brödel notes the capacity of the ureter, the pelvis, the major calices; the minor calices are approximately equal. It is of interest that each section is separated by rather strong sphincter muscles. The capacity of the renal pelvis normally varies from 1 to 20 c. c.; that of the ureter from 1 to 5 c. c.

Peristalsis.—The peristalsis observed in the ureter often enables the abdominal surgeon to identify it in doubtful cases. Lina Stern (*Thèse de Genève,* 1903, "Contractions de l'uretère") has carefully studied the phenomenon in rabbits and noted the following facts: Contraction starts at the pelvis of the kidney and descends toward the bladder at the rate of 20 to 30 mm. per second; from 3 to 6 contractions occur in a minute.

The contraction presents the following appearance: there is a swelling of the ureter from 2 to 5 mm. long, caused by its being full of urine. Immediately behind this swelling, for a distance of from 1 to 5 mm., the ureter is con-

tracted into a small, white cord. The action has been compared by Engelmann (*Arch. f. d. ges. Physiol.*, Pflüger, 1869, ii, 243) to the action of the heart. The systole is normally about half the length of the diastole; in rapid action the two become approximately equal. The duration of both systole and diastole varies from 5 to 10 seconds. The period of rest varies from 2 to 3 minutes to 3 seconds, depending on the amount of urine passing. The contractions of the ureter, as shown by experimental work on animals, is influenced by the temperature, the blood flow, the amount of urine, and through the nervous system. At 37°C. the ureter ceases to contract. At 48 degrees it again ceases. Protopopow (*Arch. f. d. ges. Physiol.*, Pflüger, 1897, lxvi, 1) was the first to show that cutting off the blood supply markedly decreased the contractions of the organs. The presence of urine is not necessary to ureteral contractions, as has been frequently observed after nephrectomy. That the presence of urine, however, does excite frequent contractions is shown by observation in the course of a polyuria. This action of the urine is largely mechanical, but undoubtedly to some extent irritative. Foreign bodies in the ureter may stimulate it to very severe contractions associated with colicky pains. This is well known in the stone colic. We have observed it frequently after allowing a catheter to remain in the ureter an hour, or after injecting a kidney to produce pain.

There are ganglion cells, particularly numerous in the vesical and pelvic ends of the ureter, throughout the organ and connected to the sympathetic system through the splanchnic nerves. Cutting the splanchnic nerves decreases the contractions of the ureter, while stimulation of the cut distal end increases them.

The Nature of the Peristalsis.—Engelmann concluded from his studies the peristaltic wave to be an automatic function of the musculature of the pelvis and ureter, and that, while it is influenced by nervous impulses, it continues to act independently of them. Small pieces of ureter removed from the body continue to contract rhythmically. Furthermore, Stern has shown that atropin has no influence on the peristalsis. It has been suggested that the wave starts from the ring of muscle around each papilla and is from thence transmitted downward.

The normal direction of the peristaltic wave is from the kidney toward the bladder; even excised portions of ureter will show the same direction of contraction. Electrical stimulation of the ureter in the body sometimes causes reverse peristalsis. Lewin and Goldschmidt (*Arch. f. path. Anat.*, etc., Virchow, 1893, cxxxiv, 61) obtained reverse peristaltic movements in rabbits by half filling the bladder with fluid and then causing it to forcefully contract.

Accompanying the reverse peristalsis, there was a reflux of fluid from the bladder to the kidney. Whether the reflux or the reverse peristalsis is primary has never been decided. Lewin and Goldschmidt thought the reflux primary: Disse takes the contrary view. Such refluxes do not occur in human beings unless the vesical orifice of the ureter is injured, and they cannot be experimentally reproduced in dogs, where the lower end of the ureter strongly suggests the arrangement found in man.

PHYSIOLOGY OF THE BLADDER.

The function of the urinary bladder is to collect the urine continuously emptied into it through the ureters; and, at irregular intervals, to discharge the accumulation out of the body through the urethra. In the normal adult the discharge is in large part under the control of the will, and its frequency is determined by the sensation of desiring to void. This sensation is only in part dependent on the amount of urine in the bladder. Normally, if promptly answered, it is a mild sensation. In abnormal states, and when it is suppressed by the will, it returns with increasing strength and can cause severe gripings and pain, until the will can no longer inhibit the emptying of the bladder, which occurs reflexly. To understand the physiology it is essential to bear the anatomy in mind, and I will here recall the essential facts.

ANATOMICAL CONSIDERATIONS.

The bladder is a muscular bag, lined by an especially adapted mucous membrane. The capacity of the bladder varies greatly, depending on the amount of urine present and the degree of relaxation of its muscles. When fully distended its lining is smooth; under other conditions, only that part composing the trigonum is smooth (Figs. 474 and 477).

Musculature of the Bladder.—The muscles of the bladder can be divided into two groups. First, those which contract and empty it (the detrusor). Second, that which closes its neck and makes possible the holding of the urine (the sphincter).

The Detrusor Muscle.—The detrusor constitutes the entire musculature of the bladder, with the exception of the ring of muscle at its neck. Although not distinctly separated, the detrusor muscle is composed of three parts: First, an outer layer of meridianally running fibers, the one pole being at the neck of the bladder, where it is inserted into the os pubis, the sphincter muscle, the trigonum and vaginal wall in the female, and the prostate in the male. Sec-

ond, a middle circular layer which comprises most of the muscle of the bladder. It is thick and in an unbroken coat, and is directly continuous at the neck of the bladder with the sphincter. Third, an inner, thin layer with fibers running in the same direction as the outer layer. It recalls the muscularis mucosa of the intestine and has doubtless a somewhat similar function. All these muscles are composed of smooth, involuntary fibers which freely anastomose with each other.

The Sphincter Muscle.—The sphincter surrounds the neck of the bladder like a ring. Its upper half in the upright posture lies considerably more dorsally than its lower half. This muscle, just like the detrusor, is composed entirely of smooth fibers. The sphincter is a very strong and thick muscle which under normal conditions is constantly in a state of tonic contraction.

Surrounding the vesical third of the urethra in the female is a muscle with striped fibers, the sphincter uro-genitalis; a part of this muscle runs around the vagina. It is represented by an analogous muscle in the male. The arrangement of the muscles at the neck of the bladder is well shown in Figure 477. Kalischer ("Die Urogenitalmuskulatur des Dammes mit besonderer Berücksichtigung des Harnblasenverschlusses," Berlin, 1900) has contributed much to our knowledge of this subject.

Mucous Membrane of Bladder.—This consists of transitional epithelium several layers thick set on a thin, fibrous sub-epithelial layer. The thickness of the mucosa varies greatly with the degree of distention of the bladder. When empty, it may measure 50 microns, when distended fully not more than 4 microns. This capacity to thin out is due, according to London, not to a displacement of cells or a squeezing out of fluid, but to a remarkable capacity of the cells to flatten out.

Blood Supply of the Bladder.—The organ is richly supplied with blood vessels, as shown in Fig. 478. They seem to have but little bearing on the physiological function of the organ.

Innervation of the Bladder.—This has been the object of many important investigations.

Among these may be mentioned those of Eckhardt[1] (1863), Stewart[2] (1899), Langley and Anderson[3] (1894 and 1895), Fagge[4] (1902), and Frankl-Hochwart and Fröhlich[5] (1900), Waldeyer and Joessel[6] (1899), and

[1] Eckhardt, C., "Beitr. z. Anat. u. Physiol.," 1860, iii, 128.
[2] Stewart, C. C., *Amer. J. Physiol.*, 1899, ii, 182.
[3] Langley, J. N., and Anderson, H. K., *J. Physiol.*, 1894, xvi, 410; 1894, xvii, 177; 1895, xviii, 67; 1895, xix, 71–131.
[4] Fagge, C. H., *J. Physiol.*, 1902, xxviii, 304.
[5] Frankl-Hochwart, L., and Fröhlich, A., *Arch. f. d. ges. Physiol.*, Pflüger, 1900, lxxxi, 420.
[6] Waldeyer and Joessel, *Lehrb. d. topog. chir. Anat.*, 1899, ii, 588.

Courtade and Guyon [1] (1900), Zeissl [2] (1893), Mosso and Pellicini [3] (1882).

The nerves to the bladder arise in a plexus of tangled fibers and scattered ganglion cells called the hypogastric plexus; it is connected with the spinal cord by two routes, to the sacral cord by the N. erigens, to the lumbar cord by way of the inferior mesenteric ganglion by the N. hypogastricus. The principal sources of fibers from the sacral cord are through the ventral branches of the second and third sacral nerves. Waldeyer states that the nerves to the bladder are connected to the sympathetic system in the upper abdomen by way of the inferior mesenteric ganglion. The arrangement and source of the nerves to the bladder vary with each species of animal. The centers in the spinal cord are connected with higher centers all the way to the brain cortex. There is a crossing of the fibers in the spinal cord at the level of the fifth lumbar nerve; Langley and Anderson state that there is a crossing outside the body in the inferior mesenteric ganglion. The centers in the brain have been worked out in animals. Marburg and Czyhlarz ("Jahrb. f. Psychiat. u. Neurol.," 1904, xx, 134), through some clinical observations on individuals with brain injuries, believe that there is a center in the motor cortex at the junction of the arm and leg centers, a second one in the corpus striatum, and a third in the optic thalamus. Stewart has shown that stimulation of any part of the spinal cord will cause the bladder to contract. Bouchefontaine was the first to note that stimulation of parts of the cortex produces a similar result.

PHYSIOLOGICAL FUNCTION OF THE BLADDER.

Theories in Regard to the Physiologic Function of the Bladder.—Kohlrausch, many years ago, suggested that the emptying of the bladder was due to the forceful contraction of the detrusor muscle alone. The opening of the sphincter, according to this view, was due to the pull upon it by the fibers of the external layer of the detrusor muscle inserted into it. Versari (*Ann. d. mal. d. org. génito-urin.,* 1897, xv, 1089) has recently again spoken of this view, now generally abandoned. It is quite impossible to conceive of the weak external layer of the detrusor muscle pulling open the tonically contracted sphincter. It may be that it gives an impulse to the sphincter which leads it to relax.

The generally accepted view to-day is that, while the anatomical structure at the neck of the bladder helps to retain the urine, as shown in the cadaver, the retaining is principally made possible by the tonic contraction of the sphincter muscle; that in the act of micturition the sphincter muscle relaxes

[1] Courtade, D., and Guyon, J. F., *Compt. rend. Acad. des sc.*, 1900, lii, 532.
[2] Zeissl, M. von, *Arch. f. d. ges. Physiol.*, Pflüger, 1893, liii, 560.
[3] Mosso and Pellicini, *Arch. ital. di biol.*, 1882, i, 291.

and the detrusor muscle forcefully contracts, expelling the urine; that to a considerable extent the expulsion can be augmented by contraction of the abdominal muscles and diaphragm; and the muscular activity is reflexly caused by a sensation which precedes the act of voiding. The stimulus which causes this sensation passes from the bladder to the central nervous system and the tonic inhibition of the brain is removed from the spinal centers, and, as a result, the urine is spontaneously passed.

That the sphincter really relaxes is shown by countless experiments; complete voiding may occur with very low intravesical pressures, and, on the other hand, very high pressures may occur without any voiding.

Origin of the Sensation of Fullness Which Normally Precedes Voiding.—Many theories have been advanced to explain this sensation. According to one, it is due to the escape of a few drops of urine into the prostatic urethra. This view originated in the experience that in certain individuals irritation of this part of the urethra produced a strong desire to empty the bladder. In many individuals it does not cause this, and, as women have the same sensation and no prostatic urethra, the matter can be dismissed.

According to another view, it is the degree of pressure in the bladder which determines it. This has much experimental evidence in its favor. It has been noted, both in human beings and in animals, that not the amount of urine but the pressure in the bladder is always the same when the patient begins to show discomfort.

Under normal conditions the mucous membrane is lacking greatly in sensitiveness, and would seem to play but a small part in this connection. When inflamed, however, it becomes very sensitive to the slightest touch, irritant or accumulation of fluid, and undoubtedly gives rise to this sensation.

Dependence of the Bladder on the Central Nervous System.—When disconnected from the brain, as normally occurs in infants and in adults with broken backs, the bladder, on reaching a certain degree of fullness, and always with the same intravesical pressure, empties spontaneously through a spinal cord reflex. Animals in which the spinal cord has been injured show the same phenomena as do human beings; for a few days after the injury there is complete retention, and this is followed by the involuntary emptyings.

When the spinal centers of the bladder are destroyed, it never regains power to completely empty itself; the amount of residual urine after each spontaneous voiding is equal. While the bladder may act independently of the central nervous system, it is nevertheless normally tremendously controlled by it. Stimulation of any sensory nerve will cause a contraction of the bladder, which, as shown by Mosso and Pellicini (*Arch. ital. di biol.,* 1882, i,

291), is much more sensitive to sensory reflex stimulation than the respiratory system. With a catheter in the bladder connected with a manometer, they noted that the slightest sensory or psychical stimulation was at once followed by a contraction of the organ. This contraction is likewise brought about in a bladder entirely isolated from the nervous system when cold water is put in it.

Whether this is due to a direct stimulation of the musculature of the bladder or through the intrinsic nervous apparatus of the viscus is not clear. While not in constant contraction, the detrusor muscle is always contracting and relaxing, according to Genouville (*Arch. de physiol. norm. et path.*, 1894, vi, 322); the desire to void comes when the intravesical pressure reaches 150 mm. of water in the average normal human individual.

Numerous methods have been employed in studying the contraction of the muscles of the bladder. Some have opened the bladder and registered the contraction directly; others have filled the bladder with water and by means of a catheter in the urethra connected it with a manometer tube; curare has been given to eliminate the influence of the voluntary muscles of the abdomen; the individual nerves have been in turn severed and the results on the bladder observed; electrical stimulations of the individual nerves and observation of the bladder have been carried out.

Studies in Nerve Stimulation.—Stimulation of the peripheral end of the cut N. erigens leads to a contraction of the side of the bladder to which the nerve belongs. Stimulation of both nerves leads to a contraction of the entire bladder. While this can be repeated many times, it has been observed by Langley and Anderson that, if the outflow of urine from the bladder be prevented, stimulation of the nerves soon ceases to cause a contraction; this recalls the frequent clinical observations that, after long retention of urine, the first effort of the bladder to contract is always a small one and accompanied by a very weak stream.

Stimulation of the N. hypogastricus produces a contraction of that part of the bladder represented by the trigonal area. The contraction follows stimulation, but is greatly more retarded than after stimulation of the connection to the sacral cord. Furthermore, after the contraction there follows a marked relaxation. There is also a contraction of the blood vessels of the bladder. By injecting nicotin intravenously, stimulation of the N. hypogastricus causes a slight contraction and a marked relaxation. If the inferior mesentery ganglion be painted with nicotin, and the hypogastric nerve then stimulated, there is nothing but a relaxation. Langley has shown that the effect of nicotin is to paralyze the ganglion cells, but not to interfere with the nerve fibers.

Stewart noted to a much less degree, after giving nicotin, a relaxation follow stimulation of the ventral roots of the sacral nerves.

The hypogastric nerve, as first shown by Courtade and Guyon, contains fibers which cause the sphincter muscle to contract. This they showed by stimulation of the peripheral end of the cut nerve. Zeissl thought that there were fibers in the N. erigens which caused the detrusor muscle to contract and the sphincter muscle to relax. That the reverse of this occurs in the N. hypogastricus is definitely demonstrated. Zeissl, in one series of experiments, connected the bladder by means of the catheter to a manometer. The catheter entered the bladder through a suprapubic fistula. With this apparatus in place, he found that by stimulating the N. erigens urine was passed through the urethra. In another series he found that, while stimulating the nerve, water could be forced into the bladder through the urethra at a lower pressure than when the nerve was not being stimulated. He interpreted these results to mean that, with stimulation of the nerve, there followed a contraction of the detrusor and relaxation of the sphincter muscles. Other observers have not been able to repeat this. Cutting of the N. erigens leads to a marked relaxation in sphincter tonus. There is a spinal center at the level of the fifth lumbar nerves which is constantly sending impulses tending to keep up the tonus of the sphincter. By destroying this center the intravesical pressure necessary to open the sphincter is much less than normal. Stimulation of the central end of the cut N. hypogastricus leads to the same result. There is little doubt that various sensory nerves have a similar effect.

Very interesting effects have been noted with various drugs. Nicotin relaxes the sphincter; morphin tends to contract it, also strychnin; atropin and cocain weaken both the detrusor and the sphincter muscles.

Frankl-Hochwart and Fröhlich found in some cases that, by stimulating the brain in dogs, they secured a relaxation of the sphincter muscle.

By very ingenious experiments, several investigators have demonstrated that there is a crossing of the nerve fibers from the two halves of the bladder at the level of the fifth lumbar vertebræ in the spinal canal. Langley and Anderson have also shown a partial crossing entirely outside the spinal canal in the inferior mesentery ganglion.

The Influence of Intra-abdominal Pressure upon Emptying the Bladder.—It is quite impossible by increasing the intra-abdominal pressure, through lowering of the diaphragm and contraction of the abdominal wall, to cause the sphincter muscle of the bladder to open and allow the passage of urine. On the other hand, entirely independently of the abdominal pressure, the bladder can easily empty itself by the contraction of the detrusor and relaxation of the sphinc-

ter muscle. When the sphincter is relaxed it is possible by means of abdominal pressure to increase the rapidity of flow of the urine. This is an experiment which can be daily observed on one's self.

General Conclusions.—The normal act of micturition transpires in the following manner: The contraction of the detrusor muscle sends centripetal impulses through sensory nerves to the spinal cord. When the pressure in the bladder reaches a certain point, these impulses become so strong that the brain becomes aware of them in the sensation which comes with an inclination to void. The brain then acts in such a way that the spinal center which keeps up the tone of the sphincter is inhibited, and the centers which tend to send out impulses to the detrusor muscle are freed of inhibiting influences which normally affect them. The result is a complete relaxation of the sphincter and the contraction of the detrusor muscle; the will may then add an increase in intra-abdominal pressure. During the act of voiding, up to a certain point, the brain can reverse these processes and cause an abrupt ending of the act. This is sometimes quite difficult, as known by common experience. When relieved of the influence of the brain, the spinal centers act automatically as in the infant. A centripetal impulse from the distended bladder causes a relaxation in sphincter tonus and a stimulation of the detrusor muscle to strong contraction. The bladder tends to act automatically, as shown in experimental work on animals quite independently of all central nervous influence.

The sphincter uro-genitalis ordinarily plays no part in closing the neck of the bladder. It is occasionally called into action when violent efforts are made to prevent voiding. Its action is of very short duration.

CHAPTER VI.

EXAMINATION OF THE URINE.

One of the first and most important steps toward a diagnosis of the condition of the urinary organs rests upon a thorough examination of the urine. Such an examination embraces investigation of its physical, chemical, microscopical and cultural properties.

Normal urine contains neither pus, blood, bacteria, casts, albumin, sugar, nor other pathological element. In Chapter V we have already outlined the normal physical and chemical properties of the urine, and there are so many excellent text-books on Urinalysis that it seems unnecessary to go into the subject in detail; so important, however, is this feature of the examination that we have decided to emphasize a few of the principal points which must be gone over by every examiner in his daily routine.

HOW TO SECURE AND PRESERVE THE URINE.

For ordinary chemical and physical examinations it suffices to use fresh voided urine; for bacteriological study the urine must always be secured by catheterization; for microscopical examination voided urine may be used, but, if positive pathological findings are made out, this should be followed by the examination of a catheterized specimen. There is much more likelihood of contamination of the urine when voided by woman than by man. For physical and chemical examinations it is usually best to have the entire specimen for twenty-four hours. For microscopical and bacteriological examinations single, but often repeated, specimens should be used. Whenever possible the urine should be examined perfectly fresh, as it readily undergoes decomposition.

When it is necessary to preserve urine a few crystals of chloral hydrate should be added to the containing bottle, which should then be carefully corked. Chloroform is also a good preservative for both microscopical and chemical bodies in urine.

In bacteriological examination fresh specimens should always be employed. Twenty-four-hour specimens can best be kept in large 2,000 c. c. bottles which

are thoroughly cleaned and put in a cool place. The method of obtaining uncontaminated bladder urine in the female is shown in Figure 109.

PHYSICAL CHARACTERISTICS OF THE URINE.

The quantity, color, transparency, specific gravity, and, in some cases, freezing point and electric conductivity of the urine should be ascertained.

In disease of the urinary organs, just as in health, color is of minor importance. On the other hand, the elements found in many pathological urines render them turbid.

Normal urine is either clear, or, if turbid, can be made clear either by the addition of a little acetic acid or by heating it. Urine turbid from the presence of pathological elements is not influenced by either of these procedures.

The specific gravity of urine varies greatly, both in health and in disease of the urinary organs. Normal urine varies, depending on the amount of fluid ingested, in its specific gravity all the way from 1.002 to 1.040. As will be pointed out, it is this capacity of change which is an indication of health; pathologic urines are more likely to have fixed values. The specific gravity alone, however, gives but little indication as to either health or disease of the kidneys. Persistently low specific gravity of urines of patients, on an average amount of water and food, point to disturbances in the kidneys. A little more detailed consideration of the value of specific gravity, as well as of the freezing point and electric conductivity determinations, will be given in Chapter XI.

CHEMICAL CHARACTERISTICS OF THE URINE.

By chemical analysis the amounts of the various normal constituents of urine and the relative proportions of these substances can be determined, as well as the presence of elements which do not occur in normal urine. The persistent occurrence of some of these, such as albumin and sugar, is a well-known pointer toward disease.

On pages 192 and 193 the average normal output of fluid and the various solids for twenty-four hours is stated. The total amount of solids varies greatly with amount of food ingested, of exercise taken, and especially of fluid taken in. There are also marked individual variations. Some, as it were, are wasteful machines and burn up much fuel to secure but little energy. Others act better, and on a minimum of food give a maximum of energy. In general, it can be stated that the larger the individual the greater the amount of solids eliminated in the urine.

As shown in Chapter XI, the estimation of the various constituents in the urine for twenty-four-hour periods is of value under proper conditions in determining the functional activity of the kidney. Far more accurate information is, however, afforded by a comparison of the output of the two kidneys, to determine their relative functional capacities.

In ordinary clinical work, so far as it applies to diseases of the urinary organs, such determinations are of limited value. On the other hand, chemical analysis may show a variety of unusual elements which indicate disease of the urinary organs.

Many substances taken by mouth or injected hypodermically appear in the urine. Such products must not be considered abnormal, but merely accidental. There are, however, a number of chemical substances which are occasionally met with and which indicate either local disease of the urinary organs or some general disease, which allows metabolic products to accumulate in the blood and be passed out through the kidneys. The commonest of these substances are proteid bodies and sugars, especially serum albumin and glucose. Hardly less important are the bile pigments, melanin, various reducing substances, ferments, fat, chyle, acetone, diacetic acid, glucuronic acid, and alkapton. Of these many abnormal substances, it seems here necessary only to review the methods of finding and the significance of the proteid bodies and the sugars, likewise to briefly go over the importance of estimations of the reaction of urine.

Proteid Bodies Found in the Urine.—The principal proteids found are serum-albumin, serum-globulin, and nucleo-albumin. In addition to these are nucleo-hystin, fibrin, albumoses, peptones, blood-coloring matter. These abnormal constituents are met with under a great variety of conditions. They may be added to the urine at any point in the urinary tract. Their presence in urine without abnormal microscopical elements other than casts is evidence of kidney origin, as pointed out in Chapter VII. The presence of an excess of albumin even with blood or pus indicates at least a partial renal origin. As will be found stated in the separate chapters, albumin occurs in the urine in many kidney diseases.

Does Albumin Occur in Normal Urine?—In urine of normal healthy adults there sometimes occur traces of albumin, not detectable, however, by the ordinary tests. On the other hand, by the very delicate test of Jolles, who has modified Spiegler's procedure, almost every urine shows a little albumin. Jolles' reagent is made up in the following way: Bichlorid of mercury, 10 parts; succinic acid, 20 parts; sodium chlorid, 10 parts; water, 500 parts. The urine should be filtered, acidulated with acetic acid, and then poured over the re-

agent in a test tube just as urine is poured over nitric acid in the simple Heller's test. By this test one part of albumin, in from 150 to 300,000 parts of urine, can be determined. This small amount may be regarded as physiological. It has been repeatedly observed, after heavy physical exercise, especially if more than customary, that for several hours there may be found in the urine both albumin and casts. Prof. Menge first stated that, after palpation of the kidney, there appears albumin in the urine, in a large percentage of the cases detectable by the ordinary method; and that casts and a few blood cells frequently accompany it. In some apparently normal individuals a heavy proteid diet may be followed by the temporary presence of albumin in the urine; cold baths have a similar effect. The albumin occurring in such urines is moderate in quantity and transitory in duration. H. M. Little (*Am. J. Obst.*, 1904, L, 321) found that one-half the pregnant women in the obstetrical wards of the Johns Hopkins Hospital had albuminuria. M. Hofmeier (*Arch. f. path. Anat.*, etc., Virchow, 1882, lxxxix, 493) first called attention to the now well-known fact that many newborn children show albumin in the urine. A. W. Sterling (*Lancet*, 1887, ii, 1157) gave the name of "postural albuminuria" to a very interesting condition met with in apparently healthy people. The individuals showing this form of albuminuria are young adults. The albumin disappears when the patient lies down, and reappears on standing up. The individual may show every evidence of good health, but is more likely to be anemic and weak. W. von Leube (*Verhandl. d. Gesellsch. Deutsche Naturf. u. Aertze*, 1902, lxxiv, 222) points out that most of the cases of the so-called Culls albuminuria occur at the time of puberty in both boys and girls who are not up to normal. These children suffer with headache, giddiness, dyspepsia, and so forth. As a rule, with increasing years, the albuminuria disappears. J. Erlanger and D. R. Hooker (*Johns Hopkins Hosp. Rep.*, 1904, xii, 145) have pointed out that the amount of albumin varies inversely with the pulse pressure; that is, by use of the Erlanger blood-pressure machine they found that when the difference between the maximum and minimum pressures is low the albumin appears; when high it is absent.

In such albuminuria there is apparently no disease of the kidneys. Kraehl, who has followed several cases over long periods, considers them harmless. The same view is held by most observers. It is, however, at times quite difficult to differentiate this harmless albuminuria from that occasioned by nephritis. As a rule, the amount of albumin eliminated in functional conditions is small, but by the amount alone diagnosis is impossible. As a rule, the percentage of nucleo-albumin is greater than of serum albumin. The latter may be entirely absent. As aids to diagnosis the age of patient, condition of health,

blood pressure, and the various functional tests for the kidneys are to be considered.

Quite recently we have had under our observation a case of this type which occurred in a young man 19 years of age. He is of strong and vigorous physique. The blood pressure as obtained by Riva-Rocci apparatus was 120 mm. of Hg. There is apparently no trouble with the heart; the hemoglobin is 85 per cent. with a Dare apparatus. In this case the early morning urine contains no albumin. The afternoon specimen shows a heavy cloud by the Heller as well as the boiling test. The patient has no subjective symptoms and feels perfectly well. Phenolsulphonephthalein (6 mg.) was excreted in the proportions of 62 per cent. in the first hour and 20 per cent. in the second hour. Indigo-carmin (80 mg.) was excreted in the proportion of 9 per cent. for the first hour and 6 per cent. for the second hour. One c. c. of a $\frac{1}{2}$ per cent. solution of phloridzin induced the appearance of sugar in the urine in 10 minutes. In 3 hours 1.5 grams was eliminated. In this case we observe that the functional tests show activity of the kidneys, beyond that which one usually obtains in a normal individual. We believe that these tests are of value in all doubtful cases of albuminuria, differentiating the cases of the functional nature from those dependent on organic lesions. In this case the urine, on microscopical examination, showed no abnormal elements whatsoever.

The prognosis is good. Most cases which occur at puberty spontaneously disappear. The treatment consists in avoiding heavy exercises, avoiding all substances which irritate the kidneys, especially alcoholic, and in practicing hygienic measures.

Albuminuria Associated with Transitory and Slight Injuries to the Kidney.—After excesses in alcohol, anesthetics, and various other irritant drugs, albumin is found frequently, though temporarily, in the urine. The toxins produced by febrile conditions lead to the same condition in the kidneys and albumin in the urine. Similarly albuminurias are found in association with anemias, leukanemia, scurvy, exophthalmic goiter, jaundice, and diabetes mellitus.

Pathologico-anatomical studies of the kidneys in this group of cases show definite parenchymatous changes. As a rule, the urines show a much larger proportion of serum-albumin than of nucleo-albumin. Casts of various kinds are common. The kidney condition is secondary to a blood disease, and, provided the latter can be removed, returns to normal spontaneously.

Another kind of albuminuria is classified under the heading of "albuminuria, due to nervous diseases." Ollivier (*Arch. de physiol. norm. et path.*, 1876, iii, 2d series, 85) was the first to draw attention to this group in connec-

tion with cases of apoplexy. Albumin in the urine often accompanies epileptic attacks, migraine, and other seizures.

The celebrated experiments of Claude Bernard, who showed that injury to the cortex and various parts of the brain is followed in many animals by the presence of albumin in the urine, furnish an interesting experimental side-light upon these albuminurias of nervous diseases.

It is evident that, in addition to its occurrence in the Bright's disease and many surgical infections, albumin occurs in the urine with very little or transitory disease of the kidneys, which are extremely sensitive to deleterious influences of every kind, but show also a marked recuperative capacity.

Tests for the Proteid Bodies Found in the Urine.—The most important proteid body found in the urine, so far as pathological significance is concerned, is serum-albumin. The two routine procedures which suffice in ordinary clinical work are the well-known heat and nitric acid and cold nitric acid tests. These are so well known as to demand no special description here.

For quantitative estimation of serum-albumin, we recommend Esbach's tubes, lined to indicate the amount of reagent and of urine to be used, and calibrated to read the number of grams of albumin per liter of urine. Esbach's reagent is made up of 10 parts of picric acid, 20 parts of citric acid, and 1,000 parts of water. This reagent precipitates the globulins as well as the albumin. In ordinary work it is not necessary to separate the two proteids. As a matter of fact, the proportions of a serum-albumin and serum-globulin in different albuminurias vary markedly. The significance of these variations is not as yet understood. It seems quite likely that studies in the percentage proportions of the different proteids may yet yield valuable information as to the kind of kidney disease which is under observation.

Nucleo-albumin, which is the predominant proteid in most of the functional and physiological albuminurias, is readily detected by the two tests already given.

In a urine containing only nucleo-albumin there is no ring formed at the junction of the urine and cold nitric acid in the Heller test. On the other hand, clouds appear about half an inch above the line of junction and do not disappear, as the urate ring will, on warming. Nucleo-albumin is precipitated by cold acetic acid and also when the urine is boiled and acetic acid added. It is a constant accompaniment of pus in the urine, and is present along with the serum-albumin in many diseases of the urinary passages and kidneys.

The Reaction of Urine.—As pointed out in Chapter V, the reaction of the urine depends on the character of the diet. Meat eaters have acid, vegetable eaters alkaline, urine. On a mixed diet the highest acidity is noted

just before meals, and the lowest, usually alkalinity, during the period of the height of digestion after meals. Large amounts of sodium chlorid tend to make the urine temporarily alkaline. Sodium citrate in doses of 20 grains has a marked effect in the same direction. Muscular work seems to have but slight influence. During starvation there is constant acidity.

One frequently encounters in clinical work patients who have been told that they are suffering from acid urine, the principal symptoms being frequency and perhaps slight burning in association with micturition. The importance of this acidity of the urine is given a high place by the laity. It is true that one often meets with patients with slight cystitis, in whom, by reducing the acidity of the urine, marked relief of the symptoms is afforded. This can be done by causing a polyuria through ingestion of increased fluid, and is helped by giving twenty grains of potassium citrate, combined with fifteen drops of the tincture of hyoscyamus; independent of cystitis, marked improvement is observed in some patients after such a remedy. In many others alteration in the reaction of the urine has but little effect in relieving symptoms of this character. In normal individuals differences in reaction greatly exceeding those found in this group of cases cause no disturbances whatever. We should, therefore, prefer to describe the condition as a hyperesthesia of the bladder mucosa, rather than as hyperacidity of the urine.

Phosphaturia.—Not only acid but alkaline urines are associated with vesical disturbances. The name "phosphaturia" has been applied to a condition in which the freshly voided urine contains a heavy precipitate of earthy phosphates. Chemical examination shows that this is not associated with an increased amount of phosphates in the urine. There may be a smaller amount than normal. It is not rare, as shown by the fact that in 1,300 office patients Julius Mannaberg ("Handbuch der Urologie," Frisch u. Zuckerkandl, 1905, ii, 406) has observed eleven cases. In the majority of these there were either neurasthenic or psychic disturbances. The condition is frequently associated with disturbances of the stomach, in which the amount of hydrochloric acid secreted is small or entirely absent. With the exception of the tendency to produce phosphate stones, few symptoms referable to the urinary organs arise from this condition. The so-called phosphatic diathesis of Tiesser has few adherents to-day.

The curative treatment of this disorder is the relief of the underlying cause. In most cases the symptoms disappear on avoiding a too great vegetable diet. The taking of hydrochloric acid, urotropin, and other drugs which tend to increase the acidity of the urine can materially assist the diet.

Estimation of the Acidity of the Urine.—The quantitative determination of

the acidity of the urine is an uncertain procedure. At the present time there is no technique entirely satisfactory. The difficulties are that urinary acidity is due to a number of different chemical substances, for the most part acid salts. The acidity due to free acids is very little, only about thirty times that of water, and it is about one ten-thousandth as acid as titration would indicate.

The usual clinical method is to add an indicator like litmus, or phenolphthalein, and then run in decinormal sodium hydroxid solution, until the neutral point is reached; phenolphthalein is perhaps the best indicator.

O. Folin (*Amer. J. Physiol.,* 1903, ix, 265) recommends the following method: 25 c. c. urine are put in a small flask with one or two drops of one-half per cent. phenolphthalein solution and 15 grams of potassium oxalate, the oxalate being used to rule out the error due to the presence of ammonium salts and calcium phosphates. By this method the total acidity of the 24-hour urine of a healthy adult on mixed diet equals from 1 to 2½ grams of hydrochloric acid. Values obtained by this method surpass in accuracy results of any other procedure, but are of limited clinical value, as was stated at the beginning of this section. We do not regard the frequency and burning of micturition so commonly met with in some individuals as positively dependent on the reaction of the urine.

Sugar in Urine.—The mere presence of sugar in the urine is not an indication of renal disease. It occurs in conditions of disturbed metabolism, and especially in diabetes mellitus, as a continuous constituent of the urine. It occurs temporarily when too much sugar is ingested during periods of starvation and so forth. The only form of renal diabetes known is that due to the glucosid phloridzin. This substance has been much used in testing the functional capacity of the kidney (Chapter XI).

The two methods of quantitatively determining the amount of sugar in the urine used in urological work are the polariscopic and specific gravity tests; the first is preferable with clear urines, which can be secured by the addition of Kieselguhr in excess, followed by filtration. Occasionally crystals of the sugar of lead must be added, and the urine then filtered. All albumin must be removed. The polariscopic test furnishes not only a very easy but a very accurate method of determining the percentage of sugar in the urine, provided the precautions indicated are taken. Good instruments can be secured now at a comparatively reasonable cost.

Roberts' fermentation method, the second test, is carried out as follows: The specific gravity is determined best by use of a pyknometer, although a very accurate specific gravity spindle will do. A small piece of fresh yeast is added to the urine, which is then put at a temperature of 38°C. for twenty-four

hours. The specific gravity is then retaken and the loss in weight multiplied by 234 will give the percentage of sugar in the tested urine.

As occasional findings, one meets with free hemoglobin, mucin, fibrin, chyle, and fat in the urine, for a description of which see Chapter IX.

MICROSCOPIC EXAMINATION OF THE URINE.

This is of great value in urological work. The normal urine contains, as formed elements, in addition to deposits of urinary salts, only a moderate amount of epithelium from the urinary passages. In pathological conditions the common elements are pus, blood, bacteria, and casts. Occasionally when some part of the urinary passage communicates with the intestines intestinal contents may be present. One also meets with contents of cysts and tumors, both those primary in the urinary tract and those which have ruptured into it. Among the animal parasites found in certain conditions are the echinococcus, the embryo of filaria sanguinis hominis, and the distoma hematobium. The conditions of the urine due to these abnormal elements are treated in Chapters VII, VIII, and XXII.

Casts.—The presence of casts must be mentioned here. Castlike bodies may appear in the urine of the male subject in voided urine when the origin is from the prostate gland, as shown by Dr. George Walker, of Baltimore. All forms of casts, including the so-called cylindroids, occur in the urine obtained from the kidneys in many conditions. Casts of the urine can be found in all those conditions in which albumin is found. The formation of them is very likely to occur in transitory irritation of the kidney parenchyma. Typical blood and pus casts will point to the kidney as the source of the pus and blood.

Epithelial Cells.—Many observers claim to be able to tell by the shape of the epithelial cells found in the urine the source of these cells. If this were possible the microscopical examination of cells in the urine would be most important. As a matter of fact, the cells lining the mucous membrane of the urinary passages from the kidney pelvis down are so similar that it is quite impossible to determine their source by the morphological characteristics.

Preparation of the Urine for Microscopic Examination.—Where possible, always employ freshly voided urine. This should be centrifugalized and examined fresh and also by dried smears. The fresh specimen enables the observer to determine the presence of pus, blood, and epithelial cells, as well as bacteria; fragments of tumor, particles of stone, renal casts, and occasionally other abnormal elements are met with. The fresh specimen can be more easily studied

by the addition of Gruebler's methylene blue 2 per cent. solution, or of a 2 per cent. solution of thionin. These dyes allow a perfect differentiation of the cells, and it is not uncommon, especially with the latter, to see bacteria actively motile, deeply stained. These dyes are put in the urine which is on the slide. It is usually best to cover the whole with a thin cover glass. Dried specimens are made by obtaining smears of the sediment, allowing them to dry in the air, fixing them with heat. The ordinary laboratory stains, methylene blue, gentian violet, and carbolfuchsin, suffice for most examinations. The dried specimens are particularly of value in determining the presence and kind of bacteria. The various members of the cocci family may be readily determined on the slide, and "the slide and staining method is the one usually employed for demonstrating the tubercle bacillus" (see Chap. XIX).

Examination of the Urine for Bacteria.—This is in part carried out on the slide as indicated above, and in part by culture. For the cultural method we recommend the following procedure: The urine is obtained by catheterizing the bladder (Fig. 109), or from the kidney (Fig. 139), and collected in a sterile test tube, which is at once plugged with cotton. From this tube the urine is transferred by means of the platinum loop to culture media. For ordinary work slant agar and bouillon tubes suffice. A definite number of loops should be taken, usually two or three are enough. The inoculated tube is then placed in a thermostat and warmed to 38°C. from twenty-four to seventy-two hours. By this method all the ordinary bacteria of the urine will be discovered with the exception of the tubercle bacillus and the gonococcus, which are demonstrable on this slide.

The anaerobes and various unusual forms may fail to develop. They are, however, usually discoverable on the slide and can be grown by the use of appropriate media and methods, which are to be found in books on bacteriological methods. The reader is referred to such sources for the methods of analytically determining the various organisms found.

A fairly accurate estimation of the number of bacteria present in the urine can be made by taking three platinum loops of the sterile urine and spreading them over the surface of a slant agar tube, and then putting it in the thermostat and counting the colonies which develop in 48 hours. More accurate is the actual counting of the bacteria on a slide in proportion to the number of red blood cells obtained by mixing equal quantities of the urine and blood and making smears and staining by one of the usual blood stains. It is also feasible by mixing the urine in a blood-counting pipette with 2 per cent. thionin to actually count the organisms on the slide.

CHAPTER VII.

PYURIA, HEMATURIA, PNEUMATURIA AND HEMOGLOBINURIA.

Gas in the urine is an exceptional finding and is of limited clinical significance. Pus and blood, however, are found in many conditions where there is disease of the urinary organs, and their presence or absence contributes greatly to making an accurate diagnosis and from this proceeding to suitable treatment.

PYURIA.

Pyuria signifies pus-containing urine. This pus may enter at any point in the tract from the external urethra to the kidney, and in woman there is frequently contamination from inflamed genital organs.

FIG. 108.—PYURIA FROM SUPPURATING DERMOID CYST. (Mrs. F., Dec. 17, 1906.)

The presence of pus signifies, in general, inflammation, and so it does here in a broad way, meaning that an inflammatory condition of some sort is present in some part of the urinary tract. There are conditions, however, when there may be marked pyuria without actual inflammation of the urinary organs themselves. Examples of this sort are met with in cases of rupture of pelvic abscesses, appendical abscesses, and infected ovarian cysts into the bladder. Enormous amounts of pus may be thus evacuated, and yet no inflammation of the urinary organs proper exist. It is well to keep in mind also that there can

be inflammatory conditions of the urinary organs unassociated with pus in the urine. Such is the case when encapsulated kidney abscesses are shut off from the renal pelvis or a closed pyonephrosis of one kidney from the bladder, under which circumstances the urine may be perfectly clear and normal. A remarkable case of pyuria due to rupture of an ovarian dermoid directly into the bladder is shown in Fig. 108.

Turbidity of the Urine.—Pus gives to urine a turbid appearance. If it has recently mixed with the urine—for example, pus from the urethra—immediately after voiding it is likely to be found in flakes and little clumps floating in clear fluid; on the other hand, if pus has mixed with the urine for some time, it is more distributed and gives a diffuse turbidity. The greater the amount of pus and the longer the contact between pus and urine the more turbid the latter becomes. Turbid urine is often the first sign that attracts a patient's attention to disease; it is therefore of practical importance in inducing him to be on the *qui vive* and affords the profession grounds for diffusing easily understood instructions in general hygienic watchfulness.

Other common conditions which lead to turbid urine are bacteria, precipitates of phosphates, and carbonates in alkaline urines, and urates in acid urines. The addition of acetic acid to the urine clears up the turbidity due to phosphates and carbonates, while heat dissolves the urate deposits. The microscope must be called in to differentiate between pyuria and simple bacteriuria.

Reaction of the Urine.—There was formerly a widely current belief that pus in the urine was always associated with an alkaline reaction. Such is not the case. A pyuria may be acid, neutral or alkaline; furthermore, the reaction gives no information as to the source of the pus. An alkaline pyuria is frequently found to proceed direct from the kidney by ureteral catheterization, and, on the other hand, cystitis is most commonly associated with acid urine. The exact reverse of these conditions is also common. The main factor in determining the reaction of a pus-containing urine is the character of the infecting organism (see Bacteriuria). The common acid-forming organisms are: The bacillus coli communis, the bacillus typhosus, the tubercle bacillus, and frequently the pyogenic cocci. The alkali-forming bacteria are the bacillus alkaligenes, the bacillus pyocyaneus, the bacillus proteus, and sometimes the pyogenic cocci.

The color of the urine is not generally influenced by pus unless it is present in large quantities, when the urine takes on a dirty, greenish hue. Pus adds no odor to the urine.

The reaction of the urine has a marked influence on the pus cells in that in an acid urine they are well preserved, whereas if the urine becomes alkaline

they lose their outlines and become a homogeneous, gelatinous mass. The appearance of this mass means pus if the urine is alkaline.

Donne has utilized this reaction in developing a chemical test for pyuria. When strong solutions of sodium or potassium hydroxid are brought in contact with urines containing pus there is produced the same gelatinous material.

Pus has very little influence on the specific gravity.

The amount of pus varies greatly in different cases. There are often very few leukocytes even in normal urines. In certain cases of pyuria they may reach from 100,000 to 200,000 per c. c.

Methods for Estimating Pus.—The amount of pus in a urine may be variously determined. The microscopic method is to centrifugalize in a graduated tube. This is especially good when urine has not been too long in contact with pus. In severe cases one-half the mixture may be found to be pus. When the pus cells are evenly distributed and not clumped, their number can be actually counted by means of a blood count or as recommended by C. Posner (*Berl. klinik,* 1893, Hft. 64, 1), and Goldberg (*Berl. klin. Wochenschr.,* 1895, xxx, 1271). Posner's method of estimating the degree of pyuria by the opacity is of limited value. If a flat-bottomed glass vessel containing urine is put over ordinary printed paper the type can be read through a layer 8 cm. in thickness if the urine is clear.

Where a great many readings have to be made, and great accuracy is not required, it is of advantage to make out a scale of transparency readings as tested by actual counting of the cells. A scale once made may be used indefinitely.

The amount of pus in a urine varies with the intensity and the extent of the inflammatory process which causes it. It is impossible, however, from the amount of pus to draw any conclusions as to its source.

Microscopic Appearance of Pus Cells.—The cytology of pyuria likewise affords no basis for determining the source of pus. The larger proportion of the pus cells are polymorphonuclear leukocytes containing neutrophilic granules. There are, however, many mononuclear cells, and, occasionally, eosinophilic granulation is met with. The character of the cells does not vary with the source of the pus. In acid urine, as a rule, the cell outlines are well preserved, while in neutral or alkaline they become distorted. The relative proportion of polymorphonuclear to mononuclear cells is the same in tubercular infection as in the ordinary pyogenic infection. We have been practically unable to substantiate the findings of S. Colombino (*Ann. d. mal. d. org. génito-urin.,* 1906, xxiv, 81). In some cases of renal tuberculosis the pus cells are regular in form and in staining reaction. In many cases of old colon bacillus

pyelitis the cells may present marked irregularities in size and in staining. This is particularly well brought out with a thionin stain.

Thus it is seen that neither the nature of the infection nor the location can be determined by the kind or proportion of pus cells or by the condition of the cells. The other cell elements which accompany pus are also of doubtful value, the blood and epithelial cells associated with the pus have nothing distinctive to indicate any one particular source in the urinary tract. The many claims of ability to determine whether an epithelial cell comes from the bladder or from the pelvis of the kidney by its microscopic appearance cannot be substantiated in practice. The presence of pus casts in the urine is an exceptional finding and points to pyelonephritis.

Pus and Bacteria.—Pus in urine is nearly always associated with the presence of bacteria. In most of the ordinary pyogenic infections the bacteria are present in great numbers. An exception is found in the case of tuberculosis, where with immense amounts of pus it may be very difficult to demonstrate the bacilli; likewise the gonococcus, while not producing such marked degrees of pyuria as the tubercle bacillus, may be equally difficult to find. The demonstration of these two organisms is further made difficult by the fact that neither grows on the ordinary culture media. An apparently sterile pus in connection with the urine is, therefore, always suggestive of one of these two infections.

We would like to emphasize here the fact that when pus is found in the urine in abundance and no organism is detected either on the slide or in culture, the presumption is in favor of the pus being due to tuberculosis, and in woman almost invariably kidney tuberculosis. Every means must be taken to exclude tuberculosis before making a diagnosis. One occasionally does meet with pus in the urine in considerable amounts and yet no bacteria are present. In some of these cases it is possible that the original infecting organism has died out and disappeared.

Pus and Albumin.—The presence of pus in urine necessitates the presence of a certain amount of albumin. The amount of this albumin increases the longer the pus is in contact with the urine. It is often possible to determine roughly the pus source by the amount of albumin. As a general rule, where there is a large amount of albumin associated with pyuria its source is the kidney. The explanation of this is that when pus originates from the kidney there are very likely to be lesions there which permit the leaking of albumin from the blood. Occasionally, however, as we have repeatedly observed, there may be a true pyelitis and yet no surplus of albumin, while, on the other hand, we have frequently met with cases of cystitis associated with a large amount

of albumin. In such cases there is a bladder infection combined with a renal albuminuria.

Goldberg (*Centralbl. f. die med. Wissensch.*, 1893, xxxi, 593) was the first to work out the relations existing between the amount of pus and the amount of albumin. This author found, in cases where there was no blood and no ordinary renal albuminuria, that from 80,000 to 100,000 pus cells per c. c. produced 1 per cent. of albumin; from 40,000 to 50,000 pus cells caused $\frac{1}{2}$ per cent. of albumin; and from 15,000 to 20,000 from $\frac{1}{8}$ to $\frac{1}{4}$ per cent. Lesser numbers than this cause only a trace of albumin. Albumin of over 1 per cent. always indicates a renal source.

FIG. 109.—METHOD OF OBTAINING STERILE URINE FROM KIDNEY. Rubber sleeve removed from glass catheter. Urine allowed to flow directly into sterile test-tube.

General Considerations in Regard to Pyuria.—The pus may be present only in the first part of the urine voided, or in all the urine, or principally in that constituting the end of the micturition. Under the same pathologic conditions the amount of pus varies from time to time, and, as already pointed out, there are always other pathologic elements in the urine which contains pus. A pyuria may or may not be associated with general symptoms, such as malaise, fever, leukocytosis, renal insufficiency, etc. Frequently pain, tenderness, swelling in one part of the urinary tract in association with pyuria will indicate its source. Ofter, however, as will be pointed out in the infectious diseases of the kidney, these symptoms are prominent by their absence. In tubercular kidneys the rule is for all the symptoms to be those usually associated with diseases of the bladder.

When only the first urine voided contains pus, which may be determined by having the patient void in several glasses, carefully numbered, it is prac-

tically conclusive evidence that the source in the male is the urethra, and in the female, either the urethra or the external genital organs. Pus which readily separates and falls to the bottom of a conical urine glass on standing is practically always of vesical origin. When the pus does not separate it is either of vesical or kidney origin. As already stated, pus casts point to the kidney. Frequently a low specific gravity urine associated with pus means kidney origin. Polyuria is one of the common symptoms of pyelitis. It must be borne in mind that a cystitis and chronic interstitial nephritis may produce the same results. A differentiation can usually be made by the functional tests for kidney activity and a careful examination of the heart, arteries, and blood pressure. When albumin is present in proportions greater than 1 per cent. the presumption is in favor of the kidney origin. The character of the infecting organism is only conclusive when it is the tubercle bacillus. This always means kidney involvement in the female and likewise in the male if genital tuberculosis be excluded.

Procedures in Examination of Urine.—Catheterization of the bladder excludes pus of urethral origin (see Fig. 109). If the bladder be washed out thoroughly until clear fluid returns, and the urine which flows through the catheter left in place is pus-containing, it can be concluded with certainty that its source is outside of the bladder. This usually means the kidney, but may occasionally mean an extra-vesical abscess, which has opened into that organ.

The next step is to make a thorough cystoscopic examination. As is pointed out in the chapter on Examination, a diagnosis may be made by this examination alone. In many cases, however, the last step must be taken, which is a separate catheterization of the two ureters, and examination of the separated specimens of urine. As pointed out in Functional Diagnosis, marked lesions of the kidney may be determined by comparative functional tests, so that not only is it possible to say that the pus comes from the kidney, but it is also often easy to state what part of the kidney is involved and what is the degree of involvement. In this connection undoubted aid can be furnished by X-ray pictures, both those with and without injections of collargol.

HEMATURIA.

The many possible sources of pus in the urine are well illustrated by the accompanying figure, 110.

Bleeding from any part of the urinary tract may give rise to that mixture of blood and urine called hematuria. Most authors limit this term to those

cases where enough blood is present to be macroscopically visible. We would, however, apply it to all cases of blood in the urine. Blood, even more markedly than pus, attracts the patient's attention and takes him to a physician.

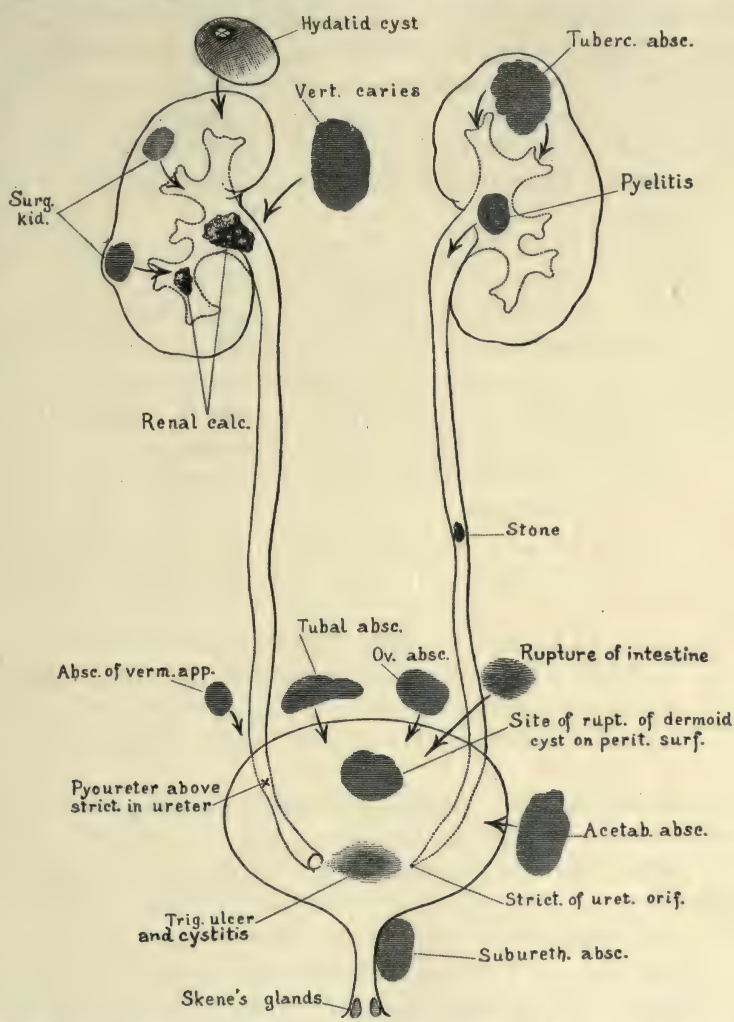


Fig. 110.—Diagram Showing Various Sources of Pus in the Urine.

Occurrence.—The frequency of hematuria, aside from that due to Bright's disease, is difficult to ascertain. In a general way it seems commoner in men than in women. It is remarkable how little attention is accorded it by many

general practitioners. It occurs very frequently, as would be expected from its numerous causes.

Source.—Blood in the urine neither indicates the part of the tract it comes from nor its causatory disease. As will be pointed out, the clinical history, the associated findings in the urine, and the physical examination of the body as a whole, and of the urinary tract in particular, must all be used as adjuncts in answering these two important questions—important because no rational therapeutic measures can be employed before the source of the bleeding and its cause are known. The following causes of HEMORRHAGE FROM THE KIDNEY have been noted:

A. Lesions of the Kidney Itself: Trauma; stone in the kidney and bladder; acute and chronic nephritis; embolism and infarct of the kidney; thrombosis of the renal veins; aneurism of the renal artery; varices and telangiectases of the kidney and its pelvis; tuberculosis of the kidney; syphilis of the kidney; tumors of the kidney; hydronephrosis; pyelitis; pyonephrosis; movable kidney; essential bleedings from the kidney; bleeding in the course of pregnancy, or during lactation; bleeding from the sudden relieving of a urinary tension in the bladder; chronic passive congestion of the kidney; arteriosclerosis of the renal vessels.

B. Peculiar Conditions of the Blood: Hemophilia; scurvy; morbus maculosus (Werlhofii); the various forms of purpura; jaundice; Barlow's disease; leukemia.

C. General Intoxications: The malignant acute fevers, especially smallpox, typhoid fever, and malaria; various acute poisons, as cantharides, turpentine, occasionally excessive doses of urotropin.

D. Certain Nervous Diseases: Tabes, multiple neuritis, and hysteria.

The following causes of HEMORRHAGE FROM PORTIONS OF THE URINARY TRACT OTHER THAN THE KIDNEY have been noted:

A. In the Ureter: Trauma; stone; tuberculosis; new growths; varices; ureteritis.

B. In the Bladder: Trauma; tumors (benign and malignant); cystitis (acute, subacute, and chronic); tuberculosis; varices; stone; hyperemia; congestion; parasitic diseases; bilharzia hematobium; filaria sanguinis hominis; echinococcus.

C. The Prostate Gland: Trauma; hypertrophy; tumors; inflammation.

D. In the Urethra: Trauma; urethritis; new growths; stone.

A glance at this long list might discourage a novice, but, as a matter of

fact, only a comparatively small number of these causes come into consideration in practice in this part of the world. A brief review of our methods for determining the source of hemorrhage must be made, and then an inquiry into the relative importance of the various kinds of hemorrhage from a surgical standpoint.

Blood may occur in the urine as the only abnormal sediment, or it may be associated with pus, bacteria, epithelial cells, fragments of tissue, gravel, or stone. The blood itself may be present in amounts so small as to be detectable only by the microscope, or the urine may be almost pure blood and every intermediate stage between these two may exist. The blood may be diffuse and in suspension, or in clots. On standing, it may separate from the urine and fall to the bottom of a conical urine glass, leaving clear urine above, or it may be diffusely distributed through the urine so as to give it the smoky appearance characteristic of acute Bright's disease. The shape of the clot is sometimes indicative of the source of the hemorrhage; this is particularly true in the large cylindrical clots from the ureters. Casts covered with blood cells also indicate its source to be the tubules of the kidney. The shorter the time the blood has been in the urine the more easily does it separate on standing in a conical glass. It is rational, therefore, to conclude that blood thus readily separating comes from the prostate or the bladder rather than the kidney.

Physical Changes in Urine Due to Blood.—The physical properties of the urine are somewhat changed by blood. The reaction is usually made alkaline; the specific gravity is not materially altered; the odor is unchanged; the color varies from a red in fresh blood to a dark brown in older blood, which is of course to be expected in view of the well-known chemical properties of hemoglobin.

Albuminuria and Hematuria.—Goldberg was the first to propose a method for accurately determining the proportion of albumin in the urine to the number of red blood cells present. If the number of red cells per c. c. in the circulating blood is known, the number of blood cells per c. c. of urine, and the total amount of urine, it is easy to estimate just how much blood has been lost into the urine. When the red blood cells are present in the urine in amounts below 3,000 per c. c. there is not enough albumin present to be demonstrated by the ordinary clinical methods. Therefore, if the urine containing blood cells is diluted with water in such proportion that the percentage of red blood cells is brought down to 3,000 per c. c., and, after testing for albumin it is found to be present, the conclusion is justifiable that the albuminuria is independent of the hemorrhage. If, for example, after dilution the red blood cells

per c. c. be 2,500, and a distinct ring of albumin show in the Heller test, it is certain that the lesion which has led to the hemorrhage also allows a leaking of albumin.

Estimation of Red Blood Cells.—The technique of counting red blood cells in the urine is like that of counting them in the blood. A well-shaken-up specimen is employed and a Thomas-Zeiss blood-counting apparatus used. The blood cells in fresh urine preserve their form remarkably well. Gumprecht (*Dtsche. Arch. f. klin. Med.,* 1894, liii, 45), as well as Senator (*Nothnagel's Spec. Path. u. Ther.,* 1902, xix, part 1), differentiate as to the blood source by the standard of preservation of the red blood cells. Such as were undergoing disintegration and were markedly degenerating they thought came from the kidney. This, however, is not the case.

As we are on the question of cytology, it is well to say that neither the epithelial nor the pus cells which may be associated with the blood cells give any inkling as to the source of the blood. The epithelium of the urinary passages is identical throughout and so is the pus that gets into the urine. When fragments of tumor are present, one can sometimes conclude that the disease is located in the bladder.

Symptoms Pointing to Source of Blood.—In the case of kidney colic and the passage of a stone the source of the blood will be evidently kidney or ureter. The blood may appear with the first portion of urine voided (initial hematuria), with the last portion voided (terminal hematuria), or mixed with all the urine; the time of its appearance is of relative importance in making a diagnosis. Initial hematuria with clear urine following means urethral hemorrhage. F. Guyon (*Ann. d. mal. d. org. génito-urin.,* 1897, xv, 113) pointed out that an initial hematuria followed by clear urine and ending in a terminal hematuria is characteristic of bleeding from the prostate gland. In the male, the hemorrhage from the posterior urethra, as well as the pus in inflammatory conditions of the urethra, runs back into the bladder and settles in the bottom, so that the first part of the urine is much clearer than the terminal portion. It is not possible, however, to speak certainly, and we have seen a terminal hematuria from a renal bleeding.

The conditions under which the bleeding occurs are likewise at times a help in diagnosis. Foreign bodies in the kidneys and in the bladder produce bleeding, when the patient is in motion, and while he is quietly at rest cause no hemorrhage. On the other hand, the exact contrary is frequently found in cases of renal, bladder, and prostatic new growths. Here, rest in bed, constipation, and hot baths may occasion severe hemorrhage.

Just as in pyuria, the entire symptom-complex must be taken into account.

For example, unusual pain or disturbance in any one organ associated with the hematuria points to that organ as its source.

Examination.—The general methods of physical examination must be carefully carried out and are contributory to exact diagnosis. Tumors of the prostate and a large prostate can be palpated, as also stones in the bladder; the kidney, when the site of hemorrhage, may be large and tender. In the end, however, all of these methods are relative and an accurate diagnosis of the source of the hemorrhage is made by special investigation of the urinary organs. This includes instrumentation with urethroscope, cystoscope, and ureteral catheter. Frequently an ordinary sounding will suffice, as in stone in the bladder. The bladder catheter is of great value. Clear urine following the introduction of a catheter and thorough washing out of the bladder indicates a urethral or prostatic source. If a large amount of hemorrhage immediately follows the washing, the source is probably bladder. If the urine is unchanged as to its blood proportions, then the assumption that we are dealing with a kidney hemorrhage is justifiable. The cystoscope enables one to locate the bladder source of hemorrhage, and catheterization of the ureters, the kidney source, which also determines whether one or both kidneys are bleeding. In this connection, as pointed out under Chapter VI, the open air cystoscope is especially valuable.

From all this it is clear that the source of the hemorrhage is only to be ascertained by careful history-taking, a detailed examination of the urinary organs, and often a thorough general examination of the patient. To the busy general practitioner it is well to recall that in women, blood in the urine means very little unless taken by a catheter. It occurs physiologically at each menstrual period, and may also rise from various diseases of the genital tract.

General Considerations.—A glance at the long list of conditions with which blood in the urine is associated will show at once that many of them can readily be differentiated by the general practitioner and that they rarely come to the attention of the urologist. Such are all the hematurias dependent upon diseases like scurvy and purpura. In every persistent case of renal bleeding it is important to determine the coagulability of the blood, as in this way some of the unusual causes of hematuria may be discovered. Likewise the hematurias associated with acute malignant fevers and those occurring after the taking of drugs present an easily recognizable group of conditions. In tropical countries only are the hematurias due to the parasites of importance, and in those lands they must be carefully investigated. In Baltimore one still meets with an occasional case of hematuria due to the malarial parasite.

The commonest form of bleeding, according to Guyon, is the hemorrhage

due to a large prostate. He has pointed out that simple hypertrophy of the prostate is quite commonly associated with severe hemorrhages, much more markedly than any other disease of the prostate. Severe hemorrhage with acute urethritis is not uncommon. The most severe bleedings are met with in cases of bladder tumor, and hemorrhages of moderate degree are present in a large proportion of cases of cystitis, the amount, however, being usually quite small. The most common cause of renal hemorrhage is, probably, Bright's disease. In most cases, however, the hemorrhage so associated is of small quantity. Julius Mannaberg ("Handbuch der Urologie," Frisch u. Zuckerkandl, 1905, ii, 381) has furnished an interesting contribution to this question. In 43 cases of acute nephritis he observed severe hemorrhage 6 times; in 45 cases of subacute nephritis, 5 times; in 200 cases of chronic nephritis, 15 times; in 16 cases of amyloid disease of the kidney, not once. In no case was the hemorrhage of an alarming nature. That very severe hemorrhages may occur from nephritis has been long recognized. Rayer ("Traité des maladies des reins," etc., 1839, iii, 354) observed such cases. Naunyn (*Mitth. a. d. Grenzgeb. d. Med. u. Chir.*, 1900, v, 639) reports three cases of fatal hemorrhage from this condition. The late Dr. George Edebohls ("Surgical Treatment of Bright's Disease," 1904, p. 56) records the successful relief of this condition by bilateral decapsulation of the kidneys.

Under separate chapters in this book is described the frequency of hematuria with the individual surgical diseases. Personally we have observed rather severe hemorrhages of renal origin in the following conditions:

Kidney stone,	29 times
Renal tuberculosis,	24 times
Pyelitis,	4 times
Kidney tumors,	12 times
"Idiopathic,"	14 times

but in no case was the hemorrhage of such extent as to immediately endanger life. In traumatic injuries it is always present and may be most alarming.

Treatment.—The treatment, then, of a severe hemorrhage depends entirely upon the nature of the causatory condition, and for details the reader is referred to the various chapters dealing with the diseases causing hematurias. A few general directions, however, do not here seem to be out of place.

When a patient is found passing blood in the urine, the first step is to order rest in bed, and then to determine if the loss is sufficient to cause anemia or reduction in the general health. Every means should be utilized to deter-

mine the cause and source of the hemorrhage. It is rarely necessary, except in traumatic injuries, to consider the treatment of hemorrhage itself. H. Riese (*Arch. f. klin. Chir.,* 1903, lxxi, 694) has collected fifty-four cases from the literature where immediate nephrectomy has had to be done to still the hemorrhage due to ruptured kidney. In addition to rest in bed, cold applications to the skin over the organ which is bleeding are of some advantage. In certain cases it is worth while to give styptics internally. Adrenalin may be given in doses of from three to ten gr. of the dried extract of the adrenal gland or stypticin in doses of from two to four gr. every three hours. Certain cases of hematuria are also promptly relieved by the application of adrenalin to the bleeding point. This is true of urethral, vesical, and kidney infections alike. Its use in renal hematuria is described in the chapter on Essential Hematuria.

We would emphasize here again, however, that hematuria is a symptom, and that the principal indication is not to treat it, but to determine the underlying cause, and to base the treatment entirely upon this.

PNEUMATURIA.

Source of Gas in Urine.—The spontaneous passage of gas with the urine has been long noted. Brierre de Boismont, according to Kelly and MacCallum, in 1825 expressed the view that it was by the mucous membrane of the bladder, while Chomel suggested that it arose from the fermentation of the urine in the bladder.

H. A. Kelly and W. G. MacCallum (*J. Am. M. Ass.,* 1898, xxi, 375) reported one case of a primary pneumaturia from the left kidney and two cases of pneumaturia due to vesico-intestinal fistulæ. They likewise give a complete review of the literature up to the time of their publication.

Air may gain access to the urine, as suggested above, in several ways; it is always found after gas distentions for cystoscopic examinations; it is constantly present when some gas-containing, hollow viscus communicates with some part of the urinary tract (this group of cases is usually due to vesico-intestinal fistulæ); it occurs as the result of bacterial fermentation in the urine.

Gas in the Urine from Neighboring Organs.—As already stated, the cases of this group usually depend on intestino-vesical fistulæ. Under this heading the various etiological and pathological factors connected with this condition will be discussed. It will suffice here to state that the disease usually starts in an adhesion between the intestine and the bladder, and that this adhesion, through some pathological process, breaks down and leads to an

opening between the organs. Cancer, tuberculosis, and trauma are important underlying causes. In Kelly's original communication one case followed pelvic inflammatory disease and another an operation for pelvic inflammatory disease. He has recently had under observation a young man with recto-vesical fistula of unknown origin. This readily yielded to surgical treatment.

The characteristic feature of this type of pneumaturia is that, in addition to the gas, there are other elements of intestinal contents in the urine. It is of advantage in many cases to introduce coloring matter into the bowel and then look for it in the urine. A thorough cystoscopic examination will often show the mouth of the fistula. Cases of this kind invariably show inflammatory changes in the bladder and pus in the urine.

Rayer ("Traité des maladies des reins," etc., iii) mentions the condition, and in his Atlas pictures a case of fistula which unites the pelvis of the right kidney with the duodenum.

Spontaneous Formation of Gas.—This usually takes place in the bladder. Cases are on record where the fermentation has been shown definitely to occur in the kidney. These are the cases of Eisenlohr ("Beitr. z. Path. u. Physiol.," Ziegler, 1888, iii, 101); W. J. Kedrowsky (*Centrbl. f. allg. Path. u. path. Anat.,* Jena, 1898, ix, 817); F. Hitschmann and O. Lindenthal (*Sitzungber d. k. Akad. d. Wissenschaf.,* 1901, cx, 3 Abt., 93); Le Dentu ("Affections chirurgicales des reins," etc., Paris, 1889, 484); and Tisné (*Ann. d. mal. org. génito-urin.,* 1887, xv, 633).

To this most interesting group belongs one of the cases described by Kelly and MacCallum, which we will report in full:

"Mrs. J. H., age 36, married 15 years, two normal labors.

"Four months after marriage pain on voiding. Two years later passage of a stone. During next four years passage of three larger stones.

"Present trouble consists of pain and swelling in left kidney region accompanied by constant vesical distress, especially just before urination; the urine always contained pus; for one year passed gas from urethra in large amounts. Left kidney felt as a hard tumor the size of two fists.

"Cystoscopic examination: No. 10 cystoscope. Bladder mucosa normal. Right ureteral orifice easily found and normal in appearance, with the urine issuing from it clear. The left ureteral orifice found by seeing pus and gas bubbles issuing from it. These were wiped away and the ureter easily discovered surrounded by a reddish area. On pressure over the kidney pus could be squeezed out of the ureter, and mixed with the pus were numerous air bubbles. On attempting to pass a metal catheter, a stricture of the lower por-

tion of the ureter was discovered. A flexible, wax-tipped one and one-half-mm. catheter was easily passed on first attempt and entered to the kidney; no scratch marks on the wax. Pus withdrawn was thick, viscid, and of a foul odor.

"Nephrotomy was done and a drainage tube inserted into the kidney after evacuating the gas and washing out the pus which was found in its cavity. The patient made an uninterrupted recovery.

"Cultures from the kidney were not definitely successful in isolating a single organism. Coverslips from the pus showed various forms, slender bacilli in chains, stout bacilli in chains, and groups of cocci or short bacilli, beside diplococci resembling the pneumococcus. The cultures showed mainly coccus-like organisms which did not liquefy gelatin, although the growth was here, as on agar, abundant; litmus milk decolorized and coagulated with the formation of acid; no formation in lactose agar nor in urine lactose agar. Scant growth on potato and in bouillon, the bouillon becoming clouded."

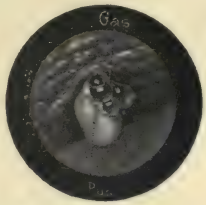


FIG. 111.—SPECULUM VIEW OF LEFT URETERAL ORIFICE, SHOWING DROP OF PUS AND BUBBLES OF GAS EMERGING FROM IT FOLLOWING PRESSURE ON KIDNEY. (Case of Mrs. J. H., Nov. 24, 1897.)

The appearance of the gas and pus issued from the ureteral orifice is shown in Figure 111.

Cause of Gas Formation.—Guiard (*Ann. d. mal. d. org. génito-urin.*, 1883, i, 846) and H. Senator were among the early investigators to point out the association of diabetes with this gas formation. In one of Senator's cases yeast cells were found in the urine. Heyse (*Centrlbl. f. innere Med.*, 1894, xv, 318) and Favre (*Beitr. z. path. Anat. u. Physiol.*, 1888, iii, 159) were among the first to demonstrate that the gas could form in urines that did not contain sugar. Schnitzler (*Internat. klin. Rundschau,* 1894) pointed out that the colon bacillus could produce in a sugar-containing urine. Many organisms related to the colon bacillus have been described in this connection. Heyse (*Ztschr. f. klin. Med.*, 1894, xxiv, 130) found the bacillus lactis aërogenes in one case; Schow (*Centrlbl. f. Bakteriol.*, 1892, xii, 745) found an organism which he calls the cocco-bacillus aërogenes vesicæ; Welch and Flexner, quoted by Kelly and MacCullum (*J. Am. M. Ass.*, 1898, xxi, 375), found in an autopsy a bladder distended with gas due to the bacillus aërogenes capsulatus.

Most of the cases of this group reported have been in elderly men suffering from obstruction in the lower urinary tract.

The gas formation is rarely of sufficient extent to occasion any disagreeable

symptoms. It is merely noted by the patient. It is often, however, sufficient to give a definite tympanitic percussion note.

The variety of gas differs greatly in individual cases; carbon dioxid, nitrogen, hydrogen, oxygen, and marsh gas have all been described. The variation in gas depends upon the kind of organism, the constitution of the urine, etc.

Treatment.—The treatment of pneumaturia will depend on its cause. The gas itself is nothing but a symptom, and not an especially alarming one. Gas bacillus infections in the urinary tract yield as readily as some of the commoner infections to appropriate treatment for cystitis, pyelitis, etc.

HEMOGLOBINURIA.

Hemoglobin, independent of red blood cells, may occur in the urine during many general infectious diseases, notably in malaria, and many poisons lead to the same condition, while extensive burns likewise cause it. It is not an uncommon accompaniment of the acute infectious nephritides. In addition to these conditions in which it is a symptom, there is a peculiar and rare disease known as paroxysmal hemoglobinuria, in which individuals, usually adults, pass hemoglobin at intervals in the urine. The condition may continue for years, and is especially observed in those with a syphilitic taint. The attacks occur at irregular intervals and may or may not be associated with constitutional symptoms. These, when they do occur, are fever, chills, sometimes pain in the region of the kidneys. Usually there is a reduction in the hemoglobin of the blood before it appears in the urine. Chvostek and others have shown that in individuals subject to this condition the blood corpuscles are less resistant than normal to a variety of deleterious influences. The first urine passed containing hemoglobin contains the largest proportion of it, usually in 12 hours it is entirely passed, but albumin persists in the urine for several days.

The presence of hemoglobin is best detected by means of the spectroscope. The prognosis will depend upon the cause. Many individuals live for years with the condition. Whenever syphilis is demonstrable, it should be treated.

CHAPTER VIII.

BACTERIURIA.

The presence of microörganisms in urine has given rise to the appellation "bacteriuria," an analogous term to pyuria and hematuria.

With few exceptions pus in the urine means bacteria likewise. They are almost inseparably associated, but bacteria do sometimes occur in the urine without pus, in conditions where they cause no disease of the urinary tract but apparently merely exist as saprophytes.

In many infectious diseases they are excreted through the kidneys without much local morbid lesion. Under perfectly normal conditions, however, the urethra alone of the urinary organs is the habitat of bacteria.

Bacteria in Normal Urethra.—The bacterial flora of the healthy urethra has been thoroughly investigated by a number of careful observers. Lustgarten and Mannaberg (*Vrtljschr. f. Dermat. u. Syph.*, 1887, xiv, 905) examined eight cases in men bacteriologically; T. Rovsing, in 1890 ("Die Blasentzündungen, ihre Aetiologie, Pathogenese und Behandlung," Berlin, 1910), after extensive investigation of both male and female urethræ, concluded that practically all bacteria concerned with the production of cystitis occur in normal urethræ. Savor also (*Beitr. z. Geburtsh. u. Gynäk.*, 1899, ii, 103) carried out an extensive investigation of 142 cases, all women, ninety-three of whom were apparently healthy, and found that twenty-six had an old gonorrheal infection, and twenty-three a fresh gonorrheal one. In 36½ per cent. of the normal cases he found no bacteria whatever. The organisms found where the gonococci were not present, were the staphylococcus in twenty-two cases, the colon bacillus in fourteen, the streptococcus in four, the diplococcus in nine.

Other valuable investigations have been carried out by Hofmeister,[1] Melchior,[2] Chvostek,[3] and many others. Our personal experience leads us to believe more than half of normal individuals show bacteria in the urethra. Hofmeis-

[1] Hofmeister, "Fortschritte der Medizin," 1894, Vol. XII.
[2] Melchior, "Cystite et infection urinaire," Paris, 1895.
[3] Chvostek and Kraus. "Zur Aetiologie des Acuten Gelenkrheumatismus," Leipzig and Wien, 1898.

ter was the first to point out that the further one goes back in the urethra the fewer bacteria are present. In view of this it can readily be seen how objectionable, under the strictest care, catheterization becomes. The carrying in of bacteria through the urethra plus the possible trauma may very readily cause bladder infection.

As will be pointed out in considering inflammatory diseases of the urethra, the gonococcus is the prevalent and was at one time considered almost the solitary cause of urethritis. It is found, of course, in very many diseased urethræ.

Bacteria of Upper Urinary Passages.—The subject at hand falls naturally into two divisions: First and most important is the consideration of the bacteria which cause the infectious diseases of the bladder, ureters, and kidneys. The second is concerned with the excretion of bacteria through the kidneys from foci of infection located elsewhere in the body.

Under the separate headings of pyelitis, pyonephrosis, and cystitis are considered the facts as to the mode of entrance of bacteria into the urinary passages and the course of the spread of the infectious trouble that has once gained entrance. Here we desire to outline briefly those facts which seem to have a more immediate and distinct bearing on the present subject.

The celebrated Pasteur (*Compt. rend. d. l'Acad. des sci.,* 1860), as early as 1859, became convinced that ammoniacal decomposition of urine was due to a living ferment. At that time it was also believed that ammoniacal decomposition of the urine was a necessary precursor to cystitis. The experiment upon which he based his belief was the now well-known one that boiled urine in a tightly stoppered flask does not decompose; whereas, if exposed to the air, ammoniacal changes occur. Traube,[1] 1864, carried Pasteur's observation into clinical medicine, when he noted that in cases of urinary retention the reaction would remain acid as long as the bladder was left to itself, but that frequently ammoniacal decomposition of the urine followed catheterization of the bladder.

The bacteriological era, introduced by Koch, illuminated the then existing obscurity as to the nature of the ferment which caused ammoniacal changes in the urine. Among the early investigations should be mentioned those of Bouchard[2] (1886), Billet[3] (1885), Bumm[4] (1887), Clado[5] (1887), Al-

[1] Traube, *Berl. klin. Wchnschr,* 1864, i, 18.
[2] Bouchard, *Rev. de méd.,* 1886, i, 671.
[3] Billet, A., *Compt. rend. Acad. des sc.,* 1885, c, 1251.
[4] Bumm, E., *Dtsche. med. Wchnschr.,* 1887, xiii, 1057.
[5] Clado, S. G., "Etude sur une bactérie septique de la vessie." Thèse de Paris, 1887.

barran and Hallé[1] (1888), and finally the splendid and thorough work of Rovsing[2] (1890).

Rovsing's chief points were that cystitis may occur with an acid urine as well as with a urine undergoing ammoniacal decomposition. The only organism which he then placed in the acid group was the tubercle bacillus. He pointed out that the same bacteria which usually caused cystitis were present in the normal urethra; also that infection in the bladder can occur from the urethra, from the kidneys, from the blood direct to the bladder, or from an infected organ contiguous to the bladder. Cystitis, he said, was produced in the cases of ammoniacal decomposition of the urine secondary to the decomposition; that is, the bacteria cause decomposition of the urine, and the ammonia, set free, irritated the bladder and assisted the bacteria in causing inflammation. Two-thirds of his cases had acid urine.

Thomas R. Brown, of Baltimore (*Johns Hopkins Hosp. Rep.*, 1905, x, 1-89), reported investigations of 100 cases from the private clinic of Dr. Kelly, and came to the following conclusions:

1. The cause of cystitis is invariably bacteria.
2. The commonest infecting bacillus is the coli communis.
3. This organism varies markedly in virulence.
4. The bladder in woman is easier of infection than in man.
5. The contributory causes of cystitis are, anemia, malnutrition, trauma to the bladder, and, above all others, chronic passive congestion of the bladder, and especially that form due to retention of urine.
6. The most frequent avenue of infection of the bladder is the urethra.
7. Infections of the kidney are about equally divided in respect to number and to the source of infection. Practically all cases come either through ascension through the bladder, or from the blood.
8. In most cases of cystitis the urine was acid; when alkaline and from the kidney a renal stone was usually present.
9. In sixty-three cases of cystitis, the bacillus coli communis was present in thirty-one, the staphylococcus pyogenes in seven, the tubercle bacillus in six, the staphylococcus pyogenes aureus in five, the staphylococcus pyogenes albus epidermidis in four, the proteus vulgaris in two, the bacillus typhosus and the bacillus pyocyaneus each in one. In twenty cases of pyelitis the bacillus coli communis was found seven times, the tubercle bacillus six, the bacillus proteus

[1] Albarran and Hallé, "Note sur une bactérie pyogène et sur son rôle dans l'infection urinaire." *Bull. Acad. de méd.*, 1888, xx, 3rd series, 310.

[2] Rovsing, T., "Die Blasentzündungen, ihre Aetiologie, Pathogenese und Behandlung." Berlin, 1890.

vulgaris four, and the white staphylococcus two. In one case there were no organisms. In all, pure cultures of the microörganisms were obtained. The urine was invariably acid when the tubercle bacillus and colon bacillus were found and alkaline in the case of the proteus vulgaris.

10. In cases of acute cystitis a pure culture of the organism was always present, the bacillus coli communis, by far the commonest organism, causing infection in 57.7 per cent.

11. In chronic cystitis the bladder alone was involved in twenty-four cases; the cystitis was associated with pyelitis in seven. The author found the colon bacillus in pure culture in fifteen cases; in one associated with the tubercle bacillus. In five cases he found staphylococci, always in pure culture.

Suter (*Ztschr. f. Urol.,* 1907, i, 327), who contributed largely to this subject, concludes as follows: The tubercular infection of the urinary passages is in the beginning always pure; when secondary infection occurs it is almost invariably due to instrumentation. The colon bacillus can involve the bladder in cystitis either through the blood or by ascending through the urethra. The usual course of the blood infection is a pyelitis, then a cystitis. The colon bacillus is the commonest cause of infection in chronic cystitis. Acute cystitis is more commonly due to cocci. Cocci which have the power to decompose urea into ammonia can readily cause cystitis without this decomposition. The colon bacillus is much more likely to cause an ascending pyelitis than the cocci.

The most recent contribution to this subject is that of Tomoharu Tanaka (*Ztschr. f. Urol.,* 1909, iii, 431). In fifty cases—20 men, 30 women—this author found twenty-nine varieties of bacteria, in twenty-seven of which the infection was pure. He agrees with Suter and disagrees with Brown, saying that most cases of acute cystitis are due to the cocci, believing chronic cystitis most commonly due to the colon bacilli. He emphasizes the fact that the kind of organism does not determine the severity of the cystitis, and likewise points out that more acid urines are found with cystitis than alkaline. The common types of organisms which he describes are the staphylococcus pyogenes, bacillus coli communis, tubercle bacillus, gonococcus, bacillus ureæ subtilis, and the monococcus ureæ non pyogenes.

But we are not so much concerned, as the earlier investigators were, as to the kind of organism present, the reaction of the urine, or the question whether a pure or mixed infection is present. The majority of cases show infection of the urinary organs as a pure infection. Mixed infections usually mean that the secondary organism has been carried in by instruments. The com-

monest infecting organism is the colon bacillus. This was described under many names by early investigators, and for a long time it was not believed pathogenic, A. Krogius ("Récherches bactériologiques sur l'infection urinaire," Helsingfors, 1894) being the first to recognize all as allied species of the same organism. We do recognize, however, that the colon bacillus varies immensely in morphology and pathogenicity. The same marked variation in reaction to culture media is shown by the various members of the cocci family, some liquefying gelatin and some not. The probability of very marked differences in these organisms is evident from the agglutination reactions of the members of the typhoid group to blood serum. The number of so-called paratyphoid organisms has steadily increased, and it has become necessary to those carrying out Widal reactions to employ a large number of strains of bacteria in order to secure definite results. The important organisms which cause infection of the urinary passages are: the colon bacillus, the typhoid bacillus, the staphylococcus aureus, the staphylococcus albus, the streptococcus, the gonococcus, the proteus bacillus in its several forms, the tubercle bacillus, the bacillus pyocyaneus. In addition to these a great variety of organisms have been occasionally found. We have observed personally in two cases a leptothrix corresponding to the leptothrix buccalis. In both cases it was present in pure culture, and confined to the bladder, causing very severe cystitis. Before they came into our hands both cases had had repeated bladder treatments, and it is possible the leptothrix was a secondary organism which had displaced the original infection. During the last winter we had occasion to treat a most obstinate case of cystitis which had been studied by Dr. Rosenow of Chicago, who had found a pseudo-diphtheria bacillus.

Avenue of Infection.—An infection of the bladder can occur: from infection of the kidney above; from an ascension of bacteria through the urethra; from the blood direct; or from the infection of a contiguous organ.

Infection of the kidney can occur from the blood, or from the bladder through an ascension up the ureter. The kind of organism causing it has a marked influence in determining the avenue of the infection. The gonococcus infects the bladder through an ascension from the urethra. Most tubercular infections of the bladder in women are from urine coming down from an infected kidney, which has become tubercular through the blood. In the male there are many cases in which the infection of the bladder is from the prostate gland by direct contiguity. The colon bacillus may cause both bladder and kidney infection by ascension through the urethra, or the kidney may be infected first, leading to a pyelitis, the same condition existing with the pyogenic cocci and the proteus group. The exact proportion of frequency between

these two routes of infection varies greatly. In a hospital or at a clinic where there is much catheterization or intra-vesical manipulation or treatment there will necessarily be many cases where infection occurs through the urethra by what is known as the ascending route; for instance, in Brown's study nearly all of his acute cases of cystitis were post-operative, twenty-four out of twenty-six. It is of interest that fifteen were colon infections, seven staphylococcus, one typhoid bacillus, one pyocyaneus, and one a bacillus proteus. In his chronic cases of cystitis twenty-four were cystitis alone and seven associated with pyelitis. The colon bacillus was present sixteen times, the staphylococcus nine, the bacillus proteus once. In cases of acute pyelitis Brown found the colon bacillus and the bacillus proteus. In the twelve cases of chronic pyelitis, four of which were pure and eight associated with cystitis, the colon bacillus was present six times, the proteus three, the white staphylococcus once.

The results obtained in a practice among acute infectious cases are quite different, for the occurrence of bacteria and pus in the urine during typhoid fever is very common in the second and third weeks of the disease, and many of the streptococcus infections show the same tendency. We have seen a streptococcus pyelitis follow tonsillitis and in one case follow a hemorrhoid operation. It is probable that there is a greater percentage of descending infections than of ascending in cases where there has been no catheterization of the bladder; certainly in cases of pyelitis and probably also in cystitis. We are beginning to recognize more and more that many cases of chronic cystitis are due to kidney infection.

Excretion of Bacteria through Healthy Kidneys.—The investigations of Heidenhain, Maas, Wiener, and others demonstrated that solid particles of foreign matter in the blood, such as indigo-carmin and fat, could be excreted through the kidneys into the urine. This led to Grawitz's experiments with the spores of yeast, where he found that within twenty-four hours after their injection into the veins of dogs the spores appeared in the urine without exception. W. Wyssokowitsch (*Ztschr. f. Hyg.,* 1886, i, 3) experimented on dogs with the anthrax bacillus, streptococcus, and staphylococcus, and concluded the bacteria appeared in the urine only after there had been a focus of infection in the kidney. J. Orth thought this change was in the vessel walls and not visible on ordinary microscopical examination. Biedl and Kraus,[1] by a series of very careful experiments, showed that in dogs and rabbits staphylococci appeared in the urine as early as twelve minutes after being injected into a vein. The urine which contained them had no albumin and the kidneys

[1] Biedl and Kraus, *Ztschr. f. Hyg.*, 1897, xxvi, 353; Kraus, "Handbuch der Urologie," Frisch w. Zuckerkandl, 1904, i, 385.

on microscopical examination seemed perfectly normal. V. Klecki substantiated these findings. The appearance of typhoid bacilli in the urine, already spoken of, without pus or albumin, and the very large percentage of positive findings of tubercle bacilli in the urine during a case of florid tuberculosis, show that there can be but little question of bacteria being very frequently excreted through healthy kidneys. The sole condition of this excretion is the presence of bacteria in the blood. We cannot here go into the extensive literature concerning the question whether in the normal healthy condition bacteria do or do not occur in the blood.

In the chapter on examination of the urine a brief review is given of some of the methods used in identifying the common bacteria in the urine. The reader, however, is referred to books on bacteriology for important details. The existence of bacteria independent of pus and without any general infection has long been noted, and it is a common thing to find the colon bacillus persisting in the bladder after all pus has disappeared under thorough treatment. The importance of the condition lies in the fact that with the patient's lowered resistance the organism may once more set up inflammation and take on higher pathogenic qualities.

Diagnosis.—The identification of the bacteria found in the urine is made in some cases, as the gonococcus and the tubercle bacillus, on the slide. In many others the cultural methods of identification must be employed. By the cultural method, too, it is possible to determine whether one or more kinds of organisms are present. In some cases, particularly when tuberculosis is suspected, the pathogenicity of the organism is determined by animal inoculation. The actual number of bacteria present per c. c. of urine may be determined by a simple counting with an equal quantity of blood, such as has been described for making bacterial vaccines.

Treatment.—Bacteriuria independent of infection of the passages is a difficult condition to get rid of in the long-standing cases. The common typhoid bacteriuria readily yields to large doses of urotropin and abundant ingestion of water. In the more chronic cases which do not so yield, it is often necessary to carry out the various methods employed for cystitis and pyelitis.

CHAPTER IX.

EXAMINATION OF THE URINARY TRACT IN WOMEN.

By an examination of the urinary tract in women we understand a complete investigation of the normal or pathological condition of all the organs involved, from the external urethral orifice up to the cortex of the kidneys, in so far as they can be reached by our methods of investigation.

The pathological conditions of the urine have been dwelt upon in chapters on the Examination of the Urine, Pyuria, Hematuria, Pneumaturia and Hemoglobinuria, and Bacteriuria, but here we give in detail the methods of making a thorough physical examination.

The urinary tract can be investigated by palpation, percussion, sounding, inspection, ureteral catheterization. Two of these methods, percussion and sounding, have but a limited though valuable field of utilization.

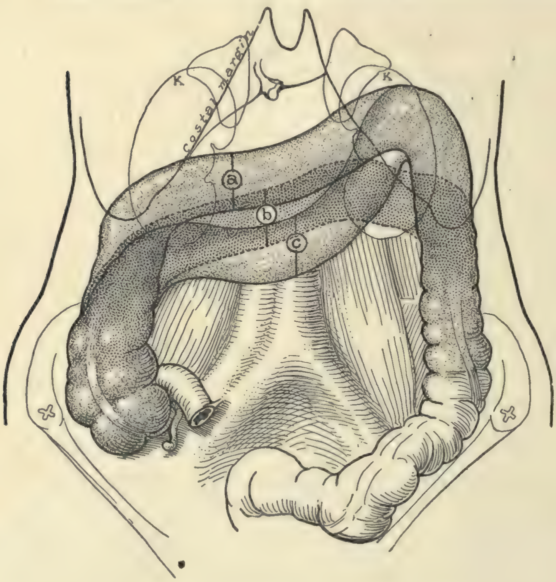


Fig. 112.—Varying Positions of the Colon in Reference to the Kidneys. Shown by *a*, *b*, and *c*. Note how much more percussion findings in reference to the right kidney may vary than those in reference to the left kidney.

PERCUSSION.

Percussion serves to outline the bladder when it is greatly distended with urine. As it fills it forms a tumor, first filling the pelvis and then extending upward toward the umbilicus. The whole area of the distended bladder is dull; its basal end attachment below at the symphysis is dull, while it is surrounded

on all sides by the tympanitic intestines. Just the contrary takes place when the bladder is distended with air. It yields a high tympanitic note, much higher in pitch than that of the intestines around it. Such an air distention of the bladder is noted after an aërocystoscopic examination, if the bladder has not been emptied of its contained air, or, more rarely, from the formation of gases within the bladder, due to the decomposition of the urine, or to a gas-forming bacillus.

Again, percussion is valuable in distinguishing a renal tumor in either flank from a solid or cystic intra-abdominal tumor. The renal tumor is marked by a tympanitic note, due to the colon which crosses the lower pole of the kidney (Fig. 112). The tympanitic area will vary somewhat with the varying position of the intestine. When the kidney is both enlarged and in descensus, as in hypernephroma or in hydronephrosis, the tympanitic area in front is a still more striking feature in the physical examination. The percussion of an enlarged kidney posteriorly to the right and to the left of the spine is, we think, an uncertain guide as to the size of the organ.

SOUNDING.

Sounding the bladder with a metal instrument is a good way to detect a stone. Used in this way, a solid metallic bougie strikes the hard foreign body with an unmistakable click, and the diagnosis is made at once. This method is more valuable in the male, where we cannot so readily explore and examine the bladder by direct inspection through an open cystoscope.

There remain three precise methods of investigating the urinary tract which we will carefully consider: palpation, inspection, and ureteral catheterization.

PALPATION.

For the purpose of palpation it is well to consider the urinary tract as divided into three segments: (1) the pelvic portion; (2) that portion which lies between the brim of the pelvis and the kidney, the abdominal portion of the ureter; (3) the renal portion (Fig. 113).

The Pelvic Portion.—In examining this portion we may again consider it as divided into three parts: the urethral, the vesical, and the two ureteral tracts.

By palpation of the urethra we note at once any large gaping urethral orifice into which the finger sometimes tends to slip; also, when, rolling the urethral

orifice from side to side under the finger, one sometimes feels two little wiry structures about 1 cm. in length, embedded in the tissues at the side of the

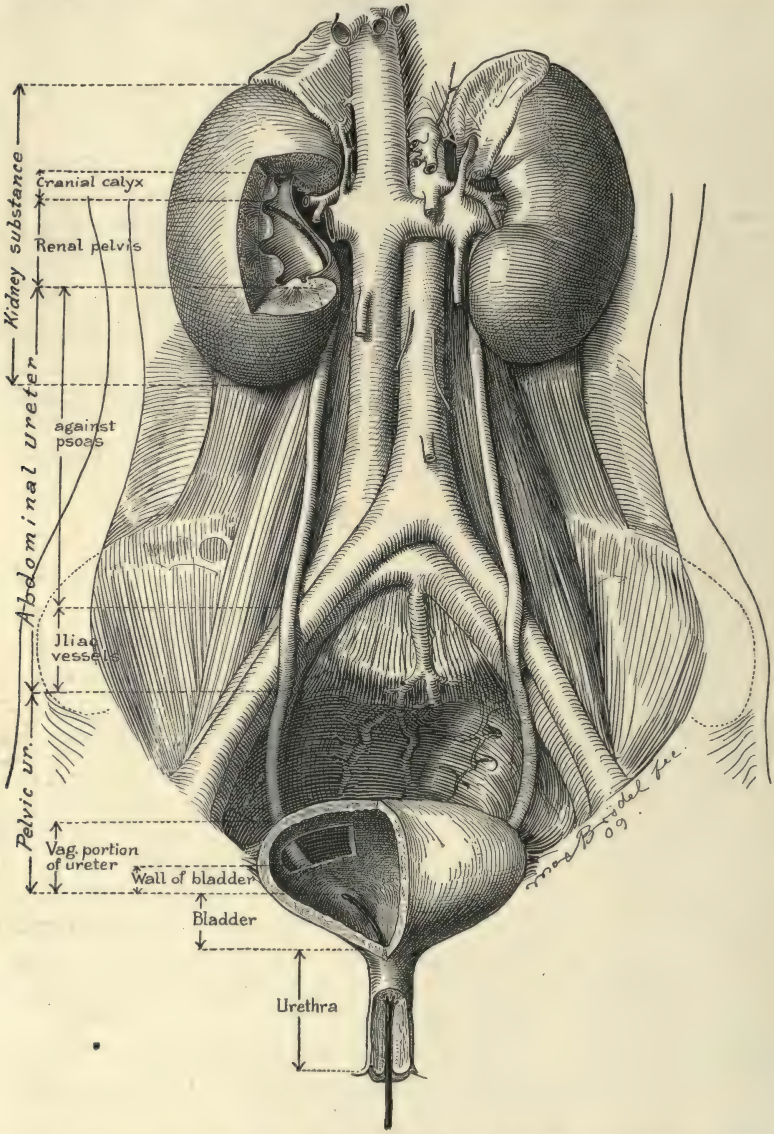


FIG. 113.—A CONVENIENT, PRACTICAL DIVISION OF THE REGIONS OF THE URINARY TRACT. From the external urethral orifice to the upper calyx of the kidney, as traversed by a renal catheter.

external urethral orifice. These are the inflamed, hardened ducts of Skene's glands. When affected in this way by chronic gonorrheal inflammation they are very much like the inflamed, hard Bartholin's ducts in the labia. On squeezing one of these glands in a direction from above downward in chronic gonorrheal cases a drop of pus can be made to exude (Fig. 114). One must not mistake for this condition the whitish, inspissated material made up simply of accumulated débris resulting from the shedding of the glandular epithelium which not infrequently accumulates to a great extent. The urethra itself, about 3 cm. in length and firmly adherent to the vaginal mucosa, is easily rolled from side to side under the finger. Any enlargement of the urethra, due to cancerous infiltration, is at once recognized by the increase in size and density. If there is a suburethral abscess this forms a cushiony enlargement the size of a hazel nut or smaller and can be emptied by pressure (Fig. 620).

FIG. 114.—MILKING THE URETHRA TO EXPRESS PUS FROM SKENE'S DUCTS.

In examining the vesico-urethral portion of the urinary tract one should

always notice any marked tendency to descensus, due to a lack of support at the pelvic floor, with a relaxation of the structures above, allowing the bladder and urethra to roll downward and outward, changing entirely the direction of the discharge of the urine and the act of voiding with any straining.

The Vesical Tract Examined by Palpation to Determine Any Enlargement or Unusual Sensitiveness.—The bladder is examined, as a rule, in an empty state, when the fingers can be brought close together and all parts of the bladder can be touched with the vaginal finger and pressed upon bimanually without causing pain or sensation of any kind. If the bladder is inflamed the patient will often complain of pain, which may be localized on one side or the other, or posteriorly. If infiltrated or enlarged so that its walls are as much as 1 cm. in thickness, even when emptied of its urine, it feels like a tumor in front of the uterus, shaped like an egg, or else a mere ill-defined, elongated mass extending up into the abdomen. Should examination give an impression that the bladder contains considerable urine when it is known to be empty, the examiner should carefully consider the question of the possibility of a vesical tumor. A foreign body may sometimes be readily felt within the bladder.

The pelvic ureteral tracts can be traced in the vagina from the ureteral orifices at the trigonum back to the broad ligaments at the side of the cervix. The normal ureters can in most cases be readily palpated bimanually. The abdominal hand, by pressing down upon the pelvis, affords a plane of resistance preventing the upward displacement of the ureter, while the vaginal hand seeks it out and rolls it from side to side under the palpating finger. This little procedure is never painful in normal cases, and the ureter can be felt like a little whipcord, not too hard, extending from the trigonum, sweeping over the anterior vaginal wall around close to the pelvic wall, but never adhering to it, to a position lateral to the cervix on either side. If the ureter is diseased it is often very tender, so tender that, on making pressure, the patient may feel an irresistible desire to urinate. The diseased ureter is almost always enlarged and feels like a hard cord, sometimes even as large as a lead-pencil or finger, uniform in size, except in tubercular cases when it is often irregular, resembling a close set string of beans. It is, as a rule, easy to distinguish an enlarged ureter by comparing it with its fellow which is rarely diseased at all, and almost never diseased to an equal extent. This little method of making a diagnosis, pointed out to us in the eighties by Max Saenger, is exceedingly valuable. A skilled diagnostician can sometimes in this way make a diagnosis in a few seconds and clear up a baffling, difficult case by a mere sweep of the finger over the anterior vaginal wall. The remaining portion

of the ureter on the left side can best be felt through the rectum. As a rule, however, this can only be done when the organ is diseased and enlarged, or when it contains a stone. Fortunately, therefore, for diagnostic purposes, the cases in which the examination is important are those most readily accessible. The technique is shown in Figure 115.

FIG. 115.—SAGITTAL SECTION OF FEMALE PELVIS, SHOWING BIMANUAL PALPATION OF LOWER END OF URETER.

The Abdominal Portion.—The abdominal portion of the ureters can only be palpated when the organ is enlarged by disease (tuberculosis), or by the presence of a stone, for a short distance from the brim of the pelvis upward in thin patients. On pressing inward over a point about corresponding to the sacroiliac joint, a tender area is reached, and then, pushing the anterior abdominal wall against the posterior wall and moving the fingers from within outward, keeping up the pressure, a cord may be felt to roll under them. In this way a large diseased ureter can sometimes be traced for a few centimeters in its course upward through the false pelvis.

The renal pelves cannot be palpated unless enlarged. Sometimes a kidney is greatly distended with stones and its pelvis rotated outward, so that the resistance afforded by the stones can be detected.

Renal Palpation.—In the average healthy patient with strong abdominal walls and a normal deposit of adipose the kidneys normally placed cannot be felt. In a thin patient, however, by making a deep bimanual pressure, pushing posteriorly with one hand just below the last ribs and pushing anteriorly inward with the other, so as to bring its fingers as nearly as possible in contact with the fingers of the posterior hand, and instructing the patient to take a deep breath, the lower pole of the kidney is felt to come down like a wedge, gently pushing the fingers apart. When the kidney is further displaced its characteristic form is easily recognized; the lower pole, the hilum or waist, and the upper pole can readily be distinguished. The organ itself is not sensitive. When diseased it undergoes certain characteristic alterations, such as changes in size, due to the formation of tumors, as hypernephroma; in sensitiveness, as in infections, particularly of the renal pelvis when pressure becomes painful; or in position, as when the kidney is displaced either congenitally or by relaxation of its supporting structures. The right kidney is usually more accessible to palpation than the left. Palpation of the diseased organs will be more fully discussed under the special chapters devoted to the various affections.

INSPECTION.

Inspection is one of the most important of all methods of investigating diseases of the urinary organs. It is combined with palpation in the examination of many diseases of the kidney, of the urethra, and the internal surface of the bladder. It is convenient in inspection to proceed with the examination in a direction from above downward, that is to say, to examine the abdominal organs first, combining inspection with a careful palpation. This gives the physician an opportunity to demonstrate to the patient the gentleness of his methods and to secure the confidence so necessary to carrying out any delicate investigation of the organs. A large displaced kidney, in the seat of the sacrum in a child, a hypernephroma in an adult, or a hydronephrotic kidney, or an enlarged, congenitally misplaced kidney situated in an iliac fossa are all readily visible on inspection, changing as they do the contour of the abdomen. If the enlarged kidney has simply been pushed down in the process of enlargement, so that it lies in contact with the diaphragm or the liver above, it may move with respiration. Inspection has its widest field in

diseases of the kidney above and of the bladder below. It is of little value between these two extremes.

Inspection of the Ureter.—Inspection of the ureter is practiced only when the abdomen is opened and the ureters are exposed to view in their pelvic portion, where they are readily seen under the peritoneum dipping down into the pelvis and coursing forward toward the base of the broad ligament. If the ureter is not seen at this point, it can easily be picked up with the fingers, unaided by sight, by simply gathering up the mass of tissues at the pelvic brim where it is crossed by the ovarian vessels; then, on letting these tissues slip between the fingers, the ureteral cord is easily recognized, and after a second or third effort retained in the fingers. Once caught up in this way it is easy to follow its course downward. If, on account of fat or thickening of the peritoneum, the ureter is not easily seen, a little incision through the peritoneum over the brim of the pelvis, just inside the ovarian vessels, will expose it to view.

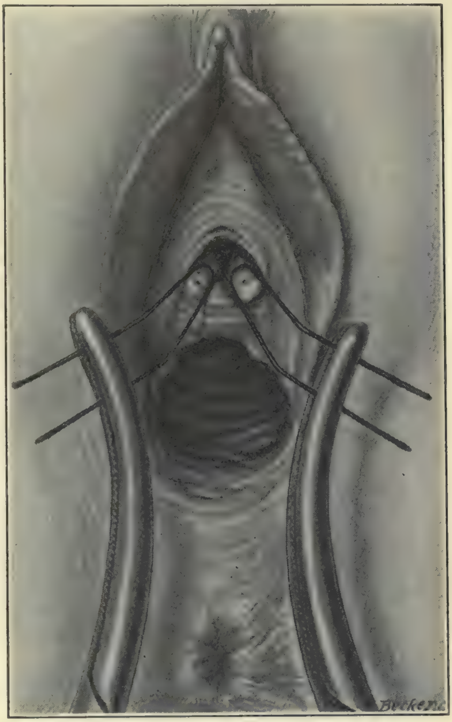


FIG. 116.—DEMONSTRATION OF THE OPENINGS OF SKENE'S DUCTS BY HAIRPIN SPECULA.

Inspection is of the utmost value in examining the lower urinary tract, namely, the urethra and the bladder, where it forms the most direct and positive method of investigating and diagnosing the diseases of these organs.

Inspection of the Urethra.—Inspection begins at the urethral orifice which, instead of appearing as normal and closed by the little delicate labia of the urethra, may in multiparæ appear gaping and red. Sometimes the orifice is found exposed, everted, shaped like a rosette, and shortened; this is due to amputation, done under the impression that the patient is suffering from "hemorrhoids"; or there may be a caruncle shaped like a cockscomb protruding from the orifice. This must not be mistaken for a chronic inflammation of the

mucosa, resulting in a thickening and eversion of the orifice, which bleeds readily on touch and is often extremely sensitive. Enlarged Skene's glands sometimes look like a pea lodged under the mucosa, and the orifice may be everted. By inspection the bulging of a suburethral abscess into the vagina is plainly visible. Above the external urethral orifice no portion of the urinary tract is visible to the naked eye unaided by instruments. A couple of bent hairpins (Fig. 116), grasped by artery forceps, form excellent retractors, exposing the outer 1 or 2 cm. of the urethra. The best instrument for inspection

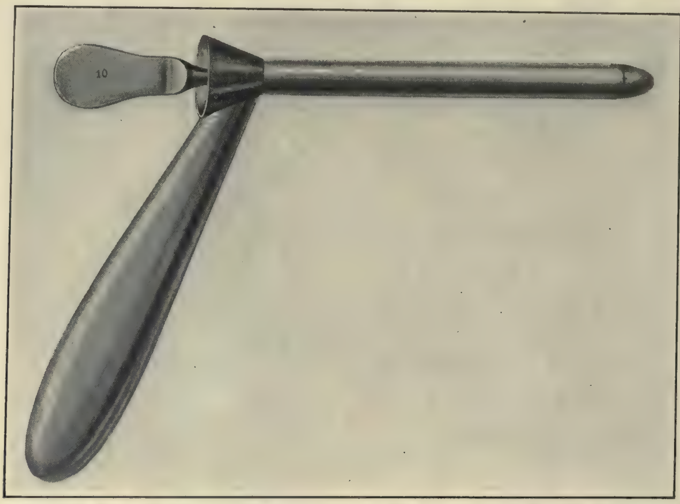


FIG. 117.—KELLY'S NO. 10 VESICAL SPECULUM. Note pointed tip of obturator, one-half natural size.

of the urethra (Fig. 117) is a short speculum of an average size, about 1 cm. in diameter and $4\frac{1}{2}$ cm. in length.

The necessary instruments for an examination are these: (1) calibrator and dilator in one; (2) head-mirror; (3) speculum; (4) evacuator; (5) searcher; (6) forceps; (7) pledgets of cotton (Figs. 117, 118, 119).

The examination is conducted with the patient on her back and placed on the table or at the edge of the bed, with flexed thighs in the lithotomy position. A ten per cent. solution of cocain is injected into the urethra with a simple medicine dropper, or is carried in on a pledget of cotton and left *in situ* for ten minutes (Fig. 120). If it is necessary to dilate the urethra, this is then done quickly on removal of the cotton with a conical dilator. The urethral speculum is then plunged well up into the bladder and the obturator withdrawn. If any urine is left in the bladder, it escapes with a gush into the vessel provided

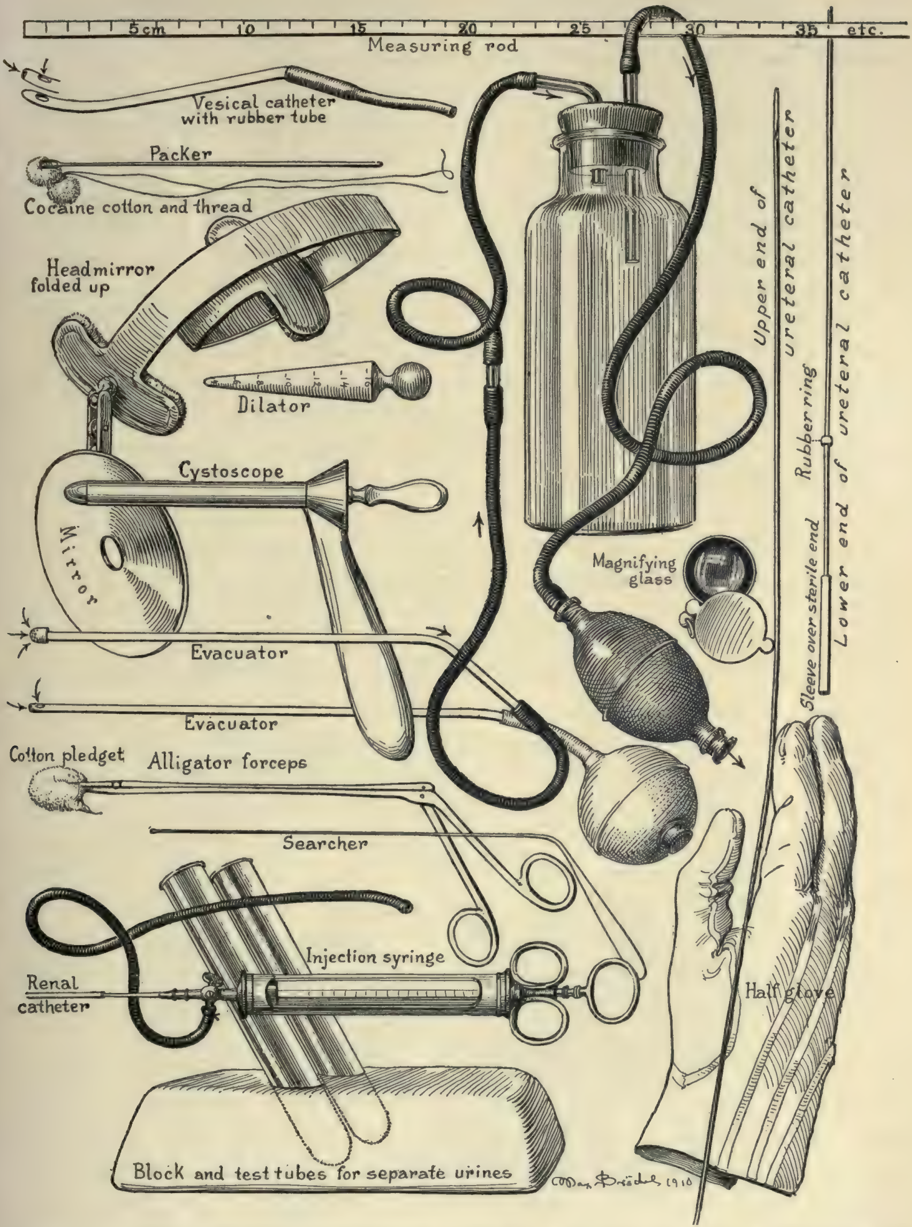


FIG. 118.—CHART SHOWING INSTRUMENTS USED IN EXAMINATION AND TREATMENT OF BLADDER, URETERAL AND KIDNEY CONDITIONS.

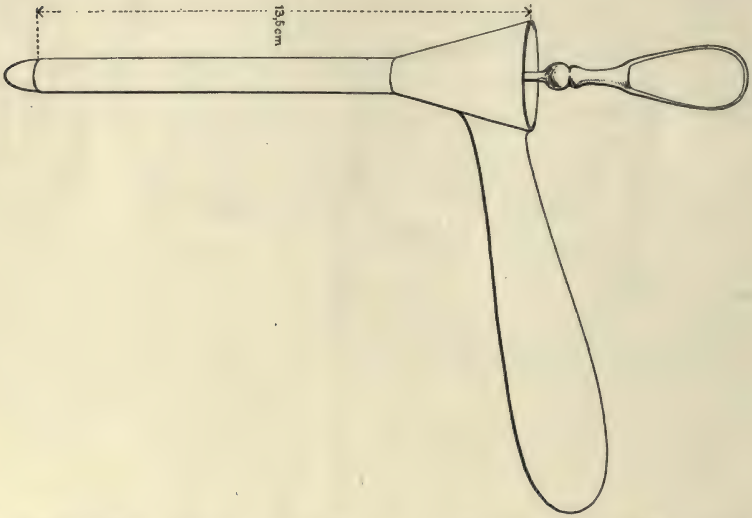


FIG. 119.—A VERY CONVENIENTLY SHAPED AND SIZED SPECULUM. (½ natural size.)

for the purpose, after which the speculum is withdrawn until the internal orifice of the urethra comes into view. An electric light reflected by a head-

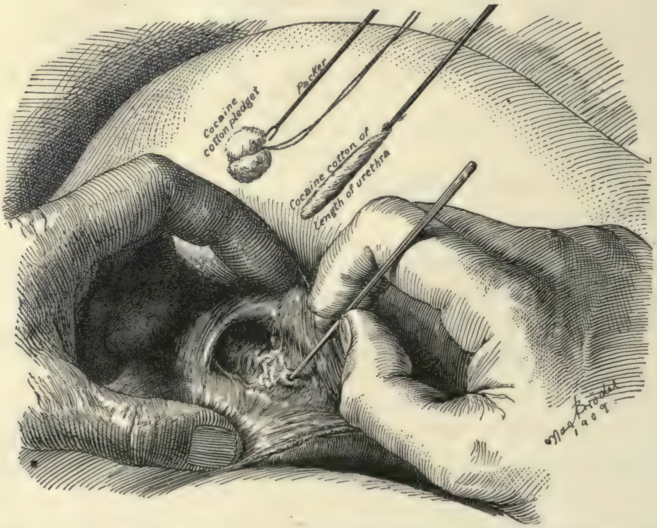


FIG. 120.—APPLICATION OF COCAIN TO URETHRA PREPARATORY TO INTRODUCING CYSTOSCOPE. Either the pledget or the applicator can be used. The strength of cocain, 10 per cent.; duration of application, 3 to 5 minutes.

S i d e P o s t u r e.—Dr. J. A. Sampson, while resident in Johns Hopkins Hospital clinic, found the elevated Sims' posture a satisfactory way of examining the air-distended bladder in patients who were too feeble to take the knee-breast posture, and especially for those cases where it was desirable to keep the patient a long time on the table. The patient is put in an ideal Sims' position, then the table is elevated. On introducing the speculum, the bladder distends with air and is open to inspection. A little more experience and skill are necessary in making an examination of this sort, but its advantages in the occasional case where it is necessary fully repay the trouble.

The Examination.—The first step in the examination is to catheterize and empty the bladder with the patient in the dorsal position. The urine thus secured is kept in a conical beaker for comparison with the urines removed later by ureteral catheterization. It is well also to set aside an uncontaminated specimen of urine taken in this way in a test-tube for careful examination in the laboratory.

In making an examination in the knee-breast posture the following instruments are necessary: (1) electric drop light; (2) head-mirror; (3) calibrator and dilator; (4) several vesical specula; (5) evacuator; (6) searcher; (7) alligator forceps; (8) 10 per cent. solution of cocain; (9) little pledget of cotton tied with a thread (Fig. 118).

The local anesthesia by means of a 10 per cent. solution of cocain is usually sufficient for a vesical examination. Sometimes when the bladder is inflamed and sensitive we follow the plan, before making the examination, of injecting about 20 c. c. of a 2 per cent. solution of novocain. This is allowed to remain in the bladder about ten minutes, when it is drawn off by a catheter, and the examination follows immediately. It is occasionally necessary to use a general anesthetic in order to make an effective examination. If the patient has an intensely inflamed bladder, as evidenced by severe pain, frequent urination and a discharge of turbid, bloody urine, it may be best to make the first examination under complete anesthesia. This is done in the ordinary position and the patient is then turned over on her side and raised up in the knee-breast position by the assistants, being held there by one assistant on either side grasping the waist with an arm, while the remaining hand grasps the leg in the crotch of the knee, and the body rests close against the thigh of the patient, thus sustaining her in an ideal knee-breast posture throughout the examination. The examination under anesthesia in this way gives the investigator a chance to explore the whole lower urinary tract, and, if deemed wise, to catheterize the ureters without distress to the sufferer.

If the patient is excessively nervous and apprehensive with regard to the

examination and lacks self-control, it is also best to make the first examination under complete general anesthesia, so that the examiner can devote his whole time and attention to the investigation of the local condition. We rarely find it necessary to continue the examinations or treatments under anesthesia, the dilatation of the urethra effected at the first examination usually being sufficient to allow the speculum to pass readily into the bladder, when the posture alone dilates the bladder, and the examination can be concluded without distress.

The next step is taking up the conical calibrator and introducing it into the urethral orifice. This serves in the first place to measure the size of the external urethral orifice, which is the only portion of the urethra that offers any resistance to the introduction of the vesical speculum. Often the urethra measures 10 mm. in diameter or more in women who have borne children. In this case no dilatation is necessary. In a urethra, however, which measures 8 or 9 mm., if the calibrator which has been lubricated with glycerin is gently pushed inward with a little twisting motion, a dilatation up to 10 mm. is easily effected within one or two seconds of time. If the urethra is a very small one, measuring only 6 or 7 mm., the dilatation need not be so great. In young women we have been able to examine the bladder and catheterize the ureters through a speculum only 6 mm. in diameter. The instrument and its method of use are well shown in Fig. 124.

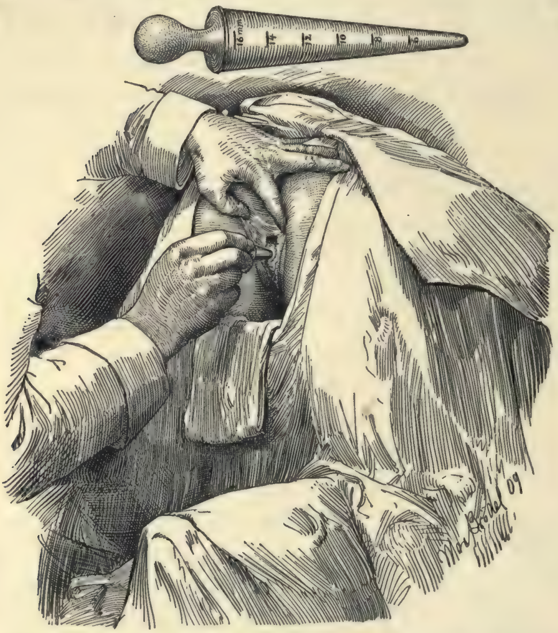


Fig. 124.—Use of Calibrator in Knee-breast Posture. Upper figure shows calibrator, one-half natural size. The calibrator is also used as a dilator in most cases.

The patient should be put on a bed with a board under the mattress, or on a table of such a height that when she is kneeling in the knee-breast posture

the urethral orifice is about opposite the face of the examiner seated in a chair. To this end a table about two feet in height is used. The operator takes his place while the patient is in position with vertical thighs and back arched in and elbows spread out and face turned to one side. The bladder has been emptied by catheterization. He now deftly lifts up the buttocks near the posterior vaginal orifice and lets air into the vagina, dropping the anterior wall of the vagina with the bladder wall on a level with the plane of vision (Fig. 125). The room is darkened by pulling down the shades, or an umbrella may be held over the head of the examiner to shut out the light. The speculum is now grasped between the thumb and first two fingers, pushing in the obturator with the handle turned down. It is then carried up into the bladder in a curved linear direction around the symphysis pubis, pointing in the last movement down in the direction of the abdominal cavity (Figs. 126 and 127).

As the obturator is withdrawn the handle of the speculum is swept around until it points upward, where it is firmly grasped. The electric drop light is held by an assistant over the sacrum of the patient, protected by a towel (Fig. 128). The examiner now directs the light caught by the head mirror until the conical opening of the speculum is the center of a large circle of light. The focal length of the head-mirror is about 12 inches, and the average size of the speculum is about 1 cm. in diameter. As the obturator is withdrawn the nurse holds a bowl under the speculum in case there is any fluid in the bladder, which may be expelled by violent breathing or other effort on the part of the patient.

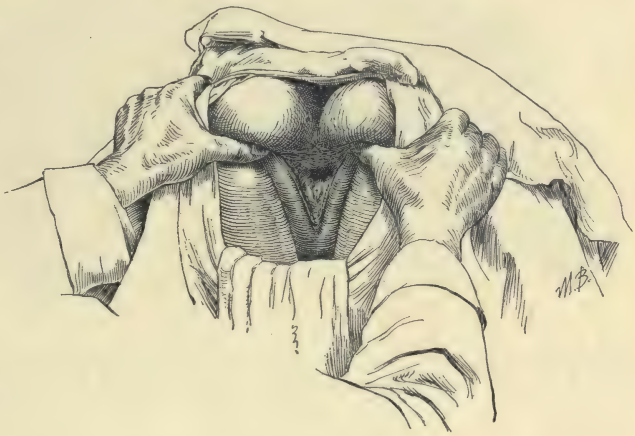


FIG. 125.—METHOD OF ADMITTING AIR TO THE VAGINA PREPARATORY TO CYSTOSCOPY IN KNEE-BREAST POSTURE. Applicable only in parous patients.

As the light is reflected down the lumen of the speculum, holding the rim of the mirror between thumb and forefinger, the examiner proceeds to look down the lumen of the speculum and to examine the bladder.

If there is any urine in the bladder, even a teaspoonful or two, it is best to remove it by applying suction by means of the simple evacuating apparatus shown in Fig. 129. When the bladder is very full it can be emptied rapidly by withdrawing the open speculum almost to the internal urethral orifice and then telling the patient to rise up vertically on her knees,

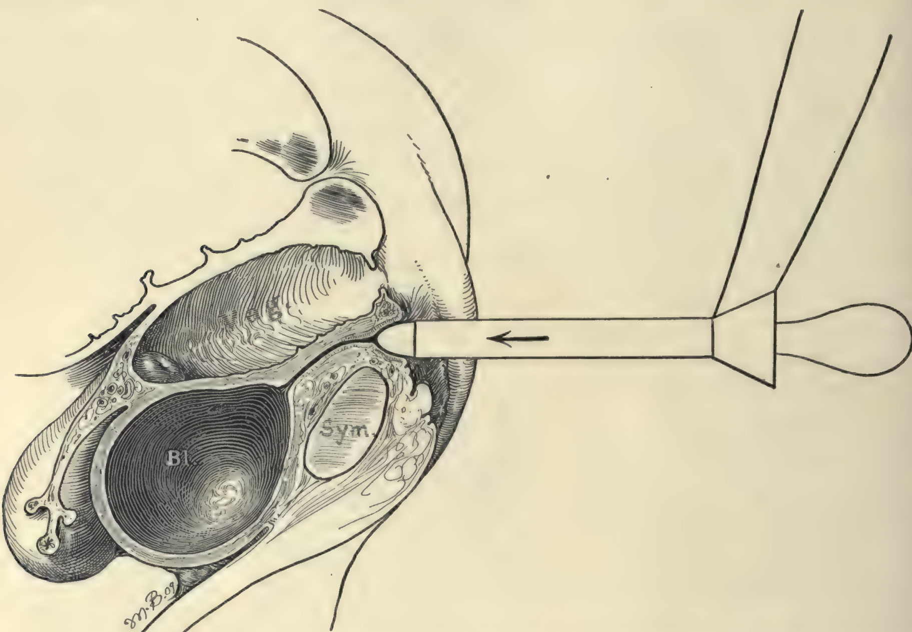


FIG. 126.—THE FIRST POSITION OF SPECULUM BEING INTRODUCED INTO THE URETHRA IN KNEE-BREAST POSTURE. Note direction of axis of speculum.

while the examiner drops the handle of the speculum. The urine then pours out in a gush.

Measurements.—The patient then resumes the knee-breast position and the inspection is continued. The form of the air-distended bladder is irregularly ovoid and measures from the internal urethral orifice, to the posterior wall 6.5 cm., to the vertex 6.5 cm., to the right cornu 3.5 cm., and to the left cornu 3.5 cm. By cornua in the bladder we mean those points to the right and left posteriorly, in front of the broad ligaments, most distant from the internal urethral orifice. These parts of the bladder are relatively fixed and determine the shape of the bladder as it collapses in discharging its urine. The method of making these measurements is, knowing the length of the specu-

lum from the vesical end to the rim, to withdraw it until the internal urethral orifice is just seen. Then, taking a graduated rod, carry it up until it touches the posterior part of the bladder. Mark off the point on the rod opposite to the outer edge of the speculum with the finger-nail and, withdrawing the rod,

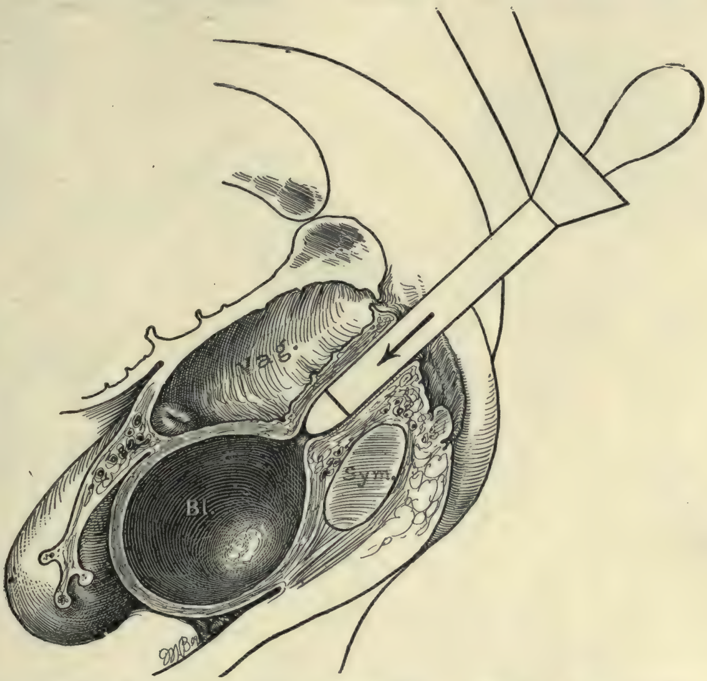


FIG. 127.—SPECULUM INTRODUCED THROUGH URETHRA TO NECK OF BLADDER. Note how speculum is now raised from horizontal position in previous figure to an angle of 45 degrees with the horizontal.

deduct the length of the speculum, when we have the distance from the internal urethral orifice to the posterior wall. Other measurements are made in the same way. A bladder with measurements decidedly below those given is contracted. The method of measuring and measurements are shown in Figs. 130, 131, 132.

Examining the Interior of the Bladder.—The examination of the interior of the bladder ought now to proceed in an orderly manner, and to include the entire inner surface, namely, the posterior hemisphere, the vertex, the right and left lateral walls, the base, the trigonum, the area behind the symphysis and around the urethra. Figs. 133, 134, 135 show diagrammatically

the various parts of the bladder to be inspected. Keeping the funnel-shaped orifice of the vesical speculum well within the larger circle of light reflected from the head-mirror, and occasionally touching the mirror to change its angle slightly, the walls of the bladder are at all times easily seen by means of the reflected light. The inspection is made by moving the speculum from side to

FIG. 128.—FIGURE SHOWING PATIENT IN KNEE-BREAST POSTURE WITH SPECULUM FULLY INTRODUCED. Note position of light, and head-mirror for illuminating bladder.

side, or up and down, in such a way as to pass rapidly in survey the entire mucous surface of the posterior wall, although at any one time a surface but a little larger than the end of the speculum is under observation. By moving the speculum about a continual visual impression is made which is practically equivalent to seeing the entire vesical surface at a glance, much in the same manner in which the eye roams about the room and secures accurate information as to all its complements by passing from object to object. This is due to the facility of persistence of vision. After viewing the posterior hemisphere in this manner the vertex is next inspected by turning the speculum

from side to side, then the right lateral wall, and, after this, the left lateral wall, turning the speculum a little more decidedly to one side or the other at an angle of about thirty degrees. One inspects the posterior wall and the vertex by looking directly down upon the surfaces, more or less at right angles to the

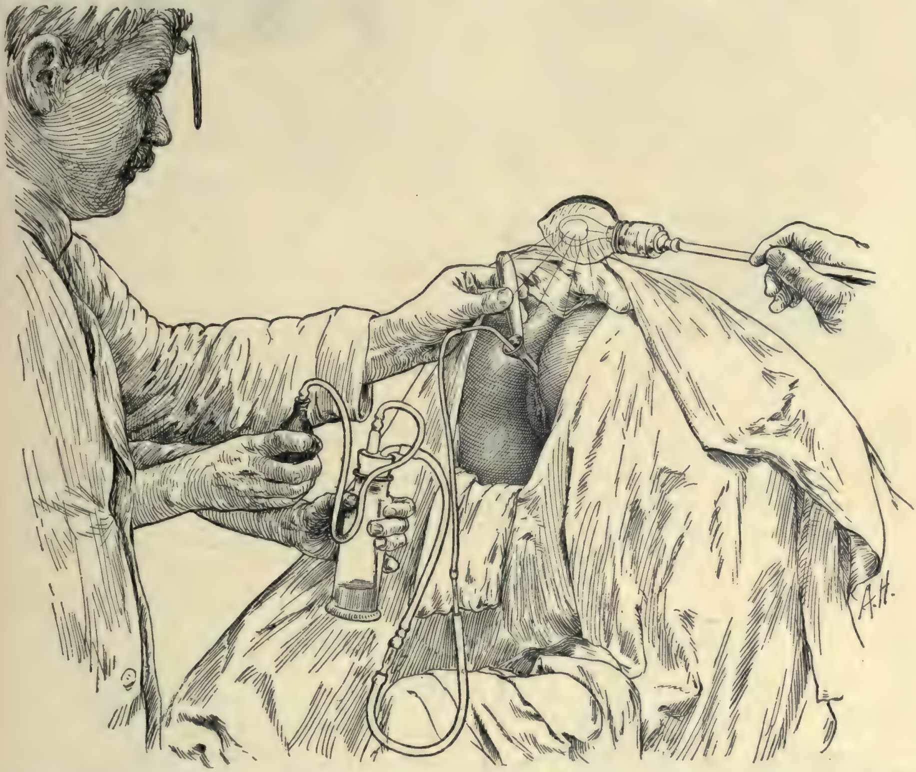
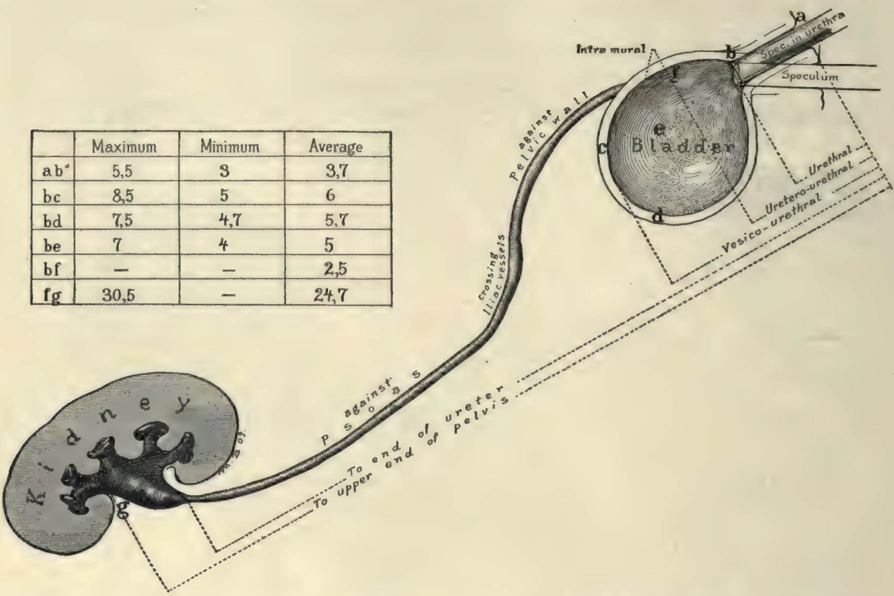


FIG. 129.—EVACUATION OF URINE FROM THE BLADDER PREPARATORY TO EXAMINATION.

plane of vision. Looking at the lateral walls there is some foreshortening, so that a larger area is seen. In order to inspect the base of the bladder the handle of the speculum is dropped decidedly, and the operator stoops lower or kneels upon a cushion on the floor, and, directing the mirror at a greater angle from the eye, he views the greatly foreshortened base. If he desires to inspect any particular part of the base more minutely, this is done by lifting up the mucosa with the upper edge of the speculum, which brings the particular area in question more into a plane at right angles to the axis of the speculum. The trigonum



	Maximum	Minimum	Average
ab'	5,5	3	3,7
bc	8,5	5	6
bd	7,5	4,7	5,7
be	7	4	5
bf	—	—	2,5
fg	30,5	—	24,7

Fig. 130.—Diagram Showing the Length of Urethra, Ureter and Pelvis, and Various Diameters of the Bladder in the Knee-breast Posture. The lettering indicates the distances measured and the table to the left, the maximum, minimum and average measurements obtained in a large series of observations.

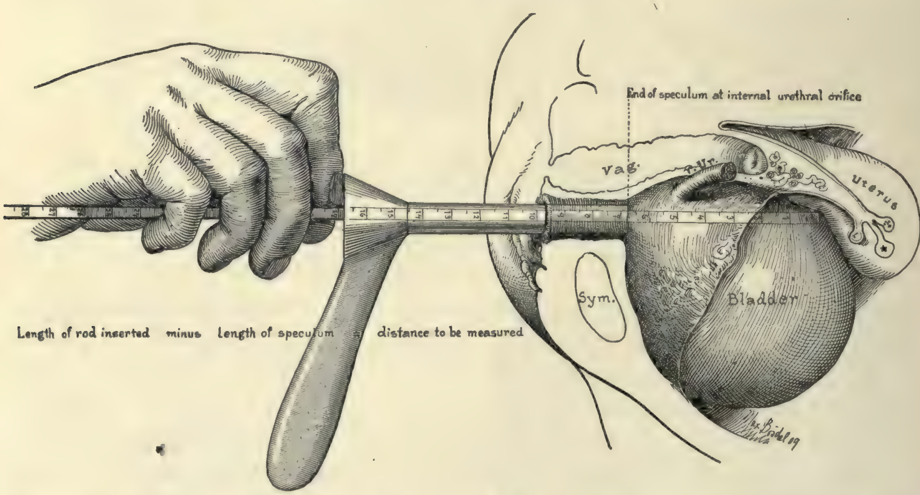


Fig. 131.—Method of Measuring Distances Between Internal Urethral Orifice and Any Point in the Bladder.

is inspected by drawing the speculum out until the internal urethral orifice begins to close over it; then pushing it in two or three millimeters, and turning it from side to side, the more hyperemic trigonum is easily seen. The prominent line between the ureteral orifices is sometimes visible, while the ureteral orifices themselves stand out on a little eminence which we call the mons ureteris on the side toward the urethra.

In examining the mucosa of the bladder the observer must be careful to take into account all of its details and its anatomical elements. In the first place, the ground color of the mucosa is pale, whitish or yellowish, in striking contrast to the congestion of an inflamed bladder. The vessels are seen everywhere on its inner surface, suggesting at first sight the ophthalmic examination of the eye. The vessels of the bladder come up from the deeper portions below and divide dendritically into finer and finer vessels, until the whole area of the bladder is tessellated by the smaller vascular ramifications and their anastomoses. In most bladders trabeculæ or prominent folds are seen stretching from a few millimeters to a centimeter or more, and often by their ramifications leaving the rest of the bladder between in the form

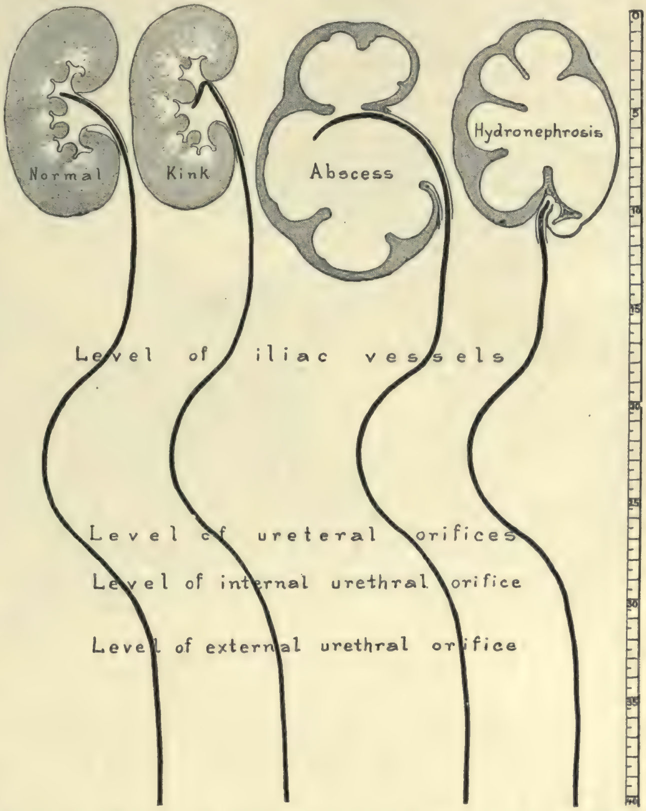


Fig. 132.—Various Shapes Which a Soft Silk-rubber Catheter Takes in Its Course up to the Kidney. A catheter allowed to stay in place a few minutes and then quickly withdrawn and put on a cold plate or in a water bath will assume the same shape it had while in the kidney.

of little crypts or pockets. These trabeculæ are formed by the inner prominent muscular fibers from the muscular coat of the bladder. Sometimes these crypts are deep, even forming diverticula; sometimes while under observation they open and close in an astonishing manner. These physiological trabeculæ

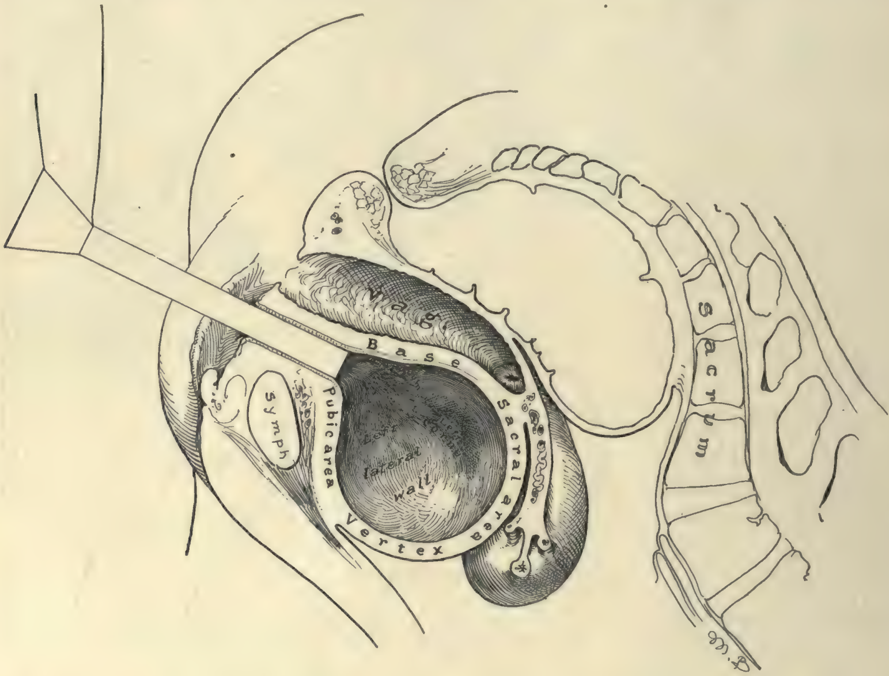


FIG. 133.—THE BLADDER IN KNEE-BREAST POSTURE, WITH SPECULUM INTRODUCED. The regions of bladder are indicated.

must not be confused with the falciform scars sometimes seen after an old cystitis.

External Anatomical Relations.—After examining the general background of the bladder for any abnormalities, and after considering certain well-defined areas within the bladder, such as the trigonum, the base, the vertex, etc., it is well to consider the bladder in its external anatomical relations; that is to say, those portions which lie in contact with the vaginal wall, corresponding to the base, the posterior wall corresponding to the uterine attachment in part, the vertex corresponding to the peritoneal surface, the lateral walls corresponding to the right and left pelvic walls, and the retrosymphyseal

area corresponding to the symphysis pubis. Each of these areas determine to a remarkable extent the diseases to which the particular portions of the bladder are liable.

An important artificial division is that into hemispheres and quadrants. These are exceedingly valuable in association with the areas already mentioned in locating and describing lesions discovered within; for example, all that concave region of the bladder opposite to the internal urethral orifice through which the examiner is looking is most naturally spoken of as

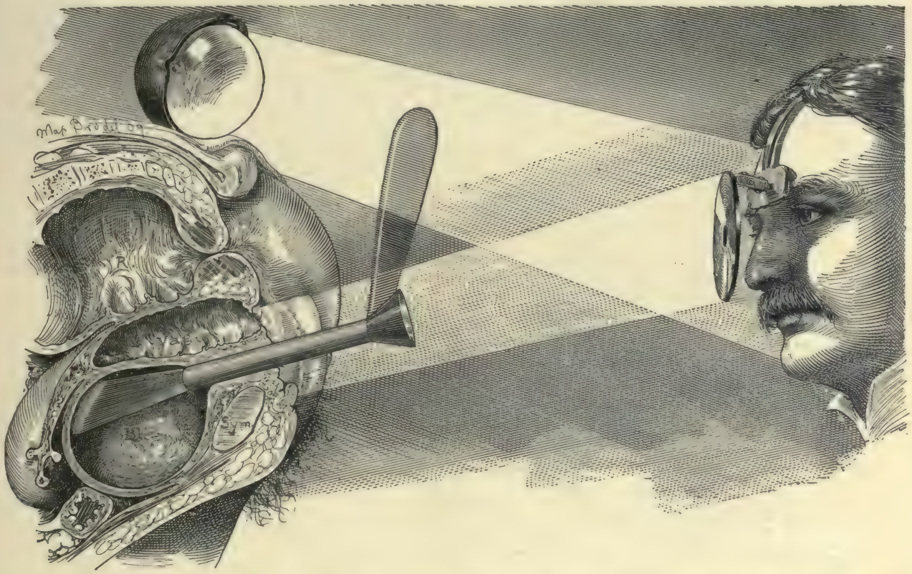


FIG. 134.—ILLUMINATION OF THE BLADDER BY CONE OF LIGHT REFLECTED FROM THE HEAD-MIRROR THROUGH SPECULUM, IN THE KNEE-BREAST POSTURE.

the posterior hemisphere, while the area surrounding the internal urethral orifice is the interior hemisphere. The latter term, however, is not so often used.

The bladder is furthermore naturally divided into right and left hemispheres by an imaginary plane bisecting the body through the sagittal suture, passing through the symphysis, and through the long axis of the speculum; so it is convenient to speak of an ordinary lesion, for example, or of tumors, as limited to the right or left hemisphere. We can furthermore subdivide the posterior hemisphere by an imaginary horizontal plane, dividing the bladder at about its center at right angles to the vertical median

plane; that is to say, we imagine the posterior part of the bladder as subdivided by two lines intersecting each other at right angles at a point about opposite the internal urethral orifice. This divides up the posterior hemisphere into quadrants. While the point for the bisection of the horizontal line is not a fixed one and will vary a little in different bladders, it is readily

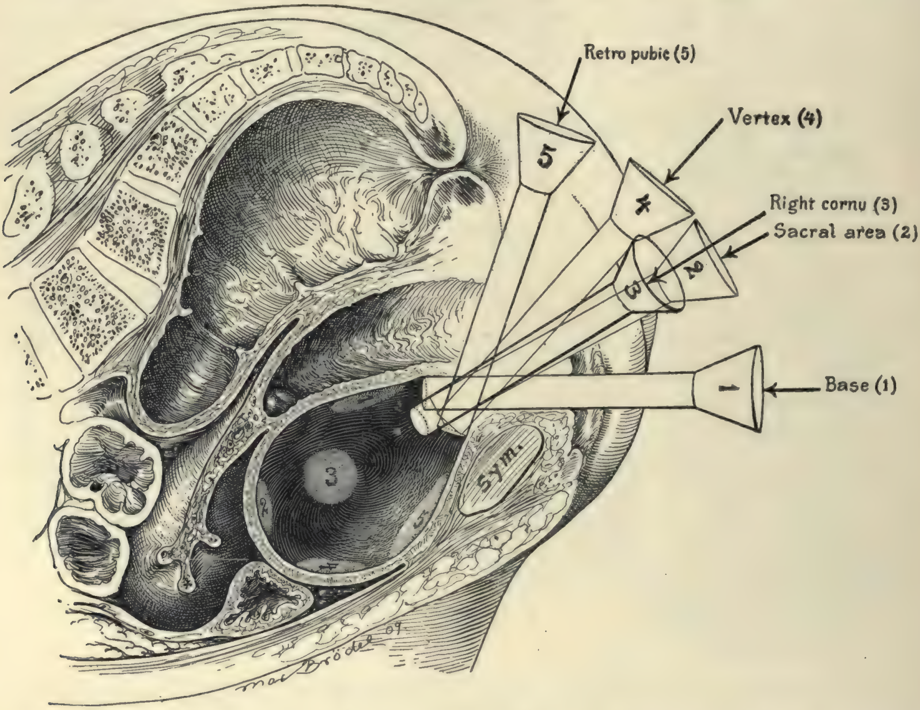


FIG. 135.—VARIOUS POSITIONS SPECULUM MAY TAKE TO ILLUMINATE ALL PARTS OF BLADDER. This is possible in female, because of short and flexible urethra.

fixed in any individual, and is valuable for the purpose of description of lesions.

With these various points of reference, particularly those which are intravesical, it is easy to locate with precision and to describe any lesion discovered within. We have also a convenient method of measuring the lesions, however irregular, with exactness, found in the diameter of the end of the speculum which can be brought into close contact with the posterior wall of the bladder, and then moved step by step, from side to side or up and down, so as to enable the observer both to describe and to measure what is noted by

the eye. It is sometimes convenient to measure the angle between the median plane and an object seen to the right or to the left. This is done by means of a goniometer, the zero point of the goniometer being kept parallel to the sagittal plane of the body, while the speculum or a rod introduced into it, touching the point observed, makes the angle with the goniometer, which is then readily read off on its scale. The trigonum is often much more deeply injected than the rest of the bladder, or rather it retains more of the normal color of the bladder when not artificially anemic by the air distention. Unless this fact is recognized, one may make the mistake of considering a normal trigonum as a seat of localized cystitis (trigonitis). The outer angles of the trigonum are marked by the presence of the ureteral eminences on which lie the ureteral orifices. These orifices are situated at an angle of about 30 degrees from the internal orifice of the urethra, and at a distance of 1.5 cm. Sometimes the orifice lies flat and flush on the vesical mucosa and no elevation can be seen. Different orifices vary widely in their appearance; occasionally they are pin-point in size; as a rule the orifice is slit-like, a little darker just around its margin, and then outside of that again a little more injected, marking it out distinctly. In other cases the orifice is like a hole, punched out in the vesical mucosa. If one looks attentively two orifices will occasionally be found on the same side. In one case there was a little slit or bridle dividing the left ureteral orifice into two slit-like openings. Occasionally a little vessel comes out of the orifice of the ureter onto the vesical mucosa. When the orifice is watched steadily for a while it will be seen to open, when a clear jet of urine spurts out from it, sometimes into the lumen of the speculum. Urine caught in this way can be examined and satisfactory conclusions drawn as to the kidney on that side without catheterization. A normal ureter opens at intervals of fifteen to twenty or thirty seconds or longer, discharges ten or fifteen drops of urine, and then relapses into quietude for a similar interval. During the ejection of the urine the ureter is lively and the urine is thrown out like a little geyser.

Finding the Ureteral Orifice.—The easiest way to find the ureteral orifice is to withdraw the speculum until the internal urethral orifice is seen, and then to carry it in just a little distance, pointed from twenty to thirty degrees to one side and looking up at the base of the bladder. If it distinctly reddens a slightly prominent area is seen. This is attentively examined until the ureter is discovered. The examiner looks patiently and goes over the area looking at every two or three millimeters until he finds a little depression or a little mark, suggesting a slit, different from the rest of the tissue. If he is uncertain he then takes a searcher (Fig. 136) and carries

it up the lumen of the speculum and introduces it into the orifice, which opens up with slight pressure. As a rule the slit-like or crescentic orifice is so

FIG. 136.—DIAGRAMMATIC REPRESENTATION OF THE FINDING OF A URETERAL ORIFICE BY MEANS OF THE URETERAL CATHETER.

evident that no reassurance of this kind is necessary. Not infrequently, while looking for a puzzling orifice, the jet of urine discloses its location. When not able to see the orifice on account of congestion, but knowing just about the point at which it is found, we have generally carried in the searcher and pushed it in parallel lines over the mucosa until it caught in the orifice, thus revealing its position. If there is inflammatory trouble spread over a considerable area around each of the ureteral orifices and the orifice is hidden in the puffy mucosa, one can often find it in this way: Locate the opposite sound orifice carefully, and then turn the speculum toward the difficult side in the same angle and relatively in the same position, neither further out nor further in, and look for it. If there is disease of the ureter the orifice is often retracted toward the cornu of that side, so that one looks for it in a position further away from the internal urethral orifice. It is very helpful sometimes in a difficult case to color the urine with indigo-carmin beforehand, when the orifice is more readily seen either by being slightly discolored itself or by means of the colored urine ejected. The following valuable facts can be ascertained by watching a ureteral orifice:

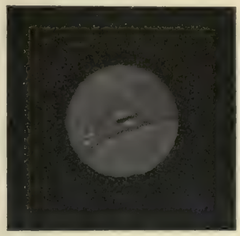


Fig. 137.—Speculum View of Normal Left Ureteral Orifice and Its Surroundings in Knee-chest Posture. The line demarking trigonum and bladder immediately behind it clearly shown.

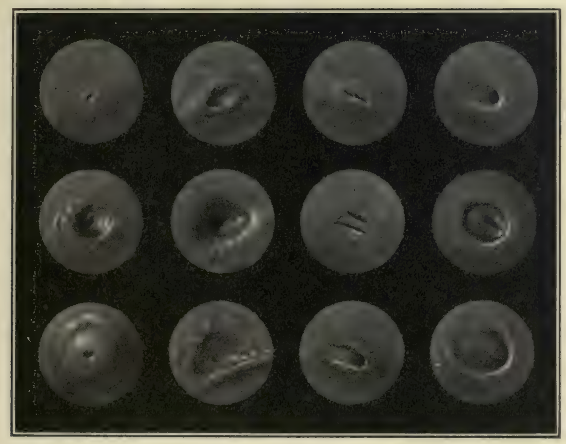


Fig. 138.—Various Types of Ureteral Orifices Drawn from Life.

Some idea of the variety in the appearance of the ureteral orifice, as it appears through the cystoscope, can be gathered from Figures 137 and 138.

(1) When the urine is intensely acid the mucosa around the ureteral orifice is often very red.

(2) A normal lively kidney is shown by the regular, active spurting with the ejection of clear urine from a ureteral orifice at intervals of a few seconds.

(3) A dead kidney may be inferred when one side spurts freely, while no

secretion can be discovered escaping from the other side after prolonged examination.

(4) Ulceration and marked swelling of the ureteral orifice show disease of the kidney of that side.

(5) A stone may be seen projecting from the ureteral orifice.

(6) A displaced orifice is the lower half of a double kidney when there are two orifices on one side.

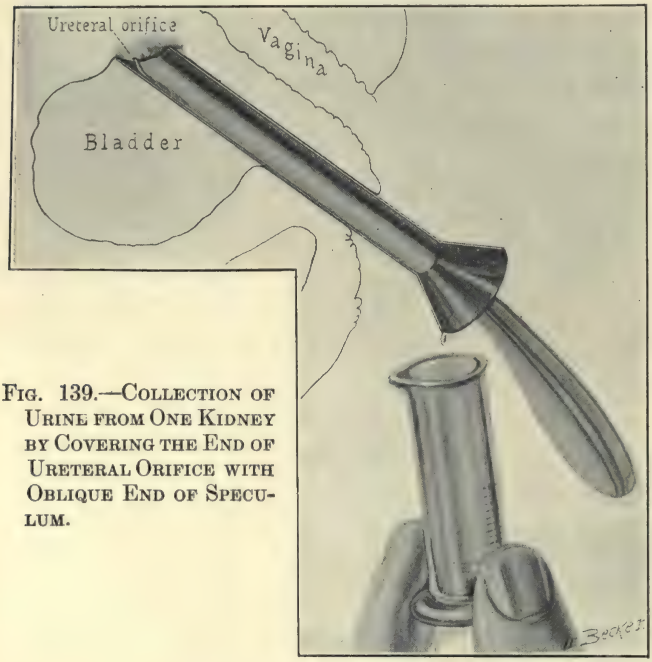


FIG. 139.—COLLECTION OF URINE FROM ONE KIDNEY BY COVERING THE END OF URETERAL ORIFICE WITH OBLIQUE END OF SPECULUM.

(7) A retracted, gaping orifice is often associated with a pus kidney above.

(8) Pus may be seen escaping from the orifice, a sure sign of pyonephrosis.

(9) Blood may be seen escaping from the orifice (renal hematuria).

(10) One of us has seen gas escaping from the ureteral orifice, arising from an infection in and around the kidney caused by a gas bacillus.

(11) A pouting orifice swelling up and pushing out into the lumen of the bladder is due to a stricture of the mucosa.

Difficulty in Finding the Orifice.—Beginners often complain of great difficulty in finding the ureteral orifice. This is due to one of several facts: (1) There is a great tendency to overlook the orifice, that is to say, to carry the end of the speculum so far into the bladder that the orifice cannot possibly be seen. This error is avoided by withdrawing the speculum until the internal urethral orifice is seen, and then pushing it in just a little distance, about one to one and a half centimeters.

(2) The patient must be in a good knee-chest position so as to keep the bladder well distended with air, and in unmarried women it is important to let air

into the vagina or into the rectum or both, so as to drop the base of the bladder to the plane of vision.

(3) It is important to look far enough to the right or left side of the orifice, about thirty degrees, in order to find the ureteral opening in its normal position.

A most valuable help is afforded by the use of the probe with the bent handle, as shown in Figure 136. Very small or concealed orifices can frequently be entered where they are practically invisible. Having once located the orifice with the searcher, it is comparatively easy to replace it with the catheter.

Urine Direct from the Kidney Without Catheterization.—One can often secure a few drops of urine, enough for chemical or bacteriological examination, direct from the kidney without catheterizing the ureter. This can be done by holding the speculum under the ureteral orifice and catching the urine as it spurts down the lumen of the speculum. H. A. Kelly has had an oblique speculum made for this purpose which facilitates the collection of urine in this way, although the ordinary speculum, No. 10, also does very well (Fig. 139).

URETERAL CATHETERIZATION.

Catheters.—The ureteral catheters are long, flexible, hollow tubes, made of woven silk covered with shellac, with an eye at one end and an opening at the other to permit the passage of the urine from the ureter or the kidney down the catheter out into a suitable receptacle. Up to the present time the best catheters are made abroad, in London or in Paris. The cost of these catheters is from one to two dollars each. The best made stand repeated sterilizations without losing their smooth surface.

The simplest and most effectual method of sterilizing renal catheters in our experience has been by the autoclave. The catheters are washed off in water, after which the stylet may or may not be introduced. They are then put in towels, each towel containing several catheters of a given size; the towel is folded and pinned together, put in the autoclave with dressings, and sterilized. They are kept in this towel until they are ready for use.

It is also possible to sterilize catheters by rinsing them out and soaking them in a 4 per cent. formalin solution for at least 5 hours. They can then be thoroughly rinsed out in sterile water and put in sterile towels until used.

When a patient, generally a case of renal infection, needs repeated catheterizations, it is a good plan to set aside one or two catheters for the exclusive

use of that particular patient. The hollow catheters are often too flexible to be pushed up the ureter into the kidney by themselves, and for this reason they are armed with a stylet, made of copper wire, which passes through the whole lumen of the speculum up to the eye. One must be very careful, how-

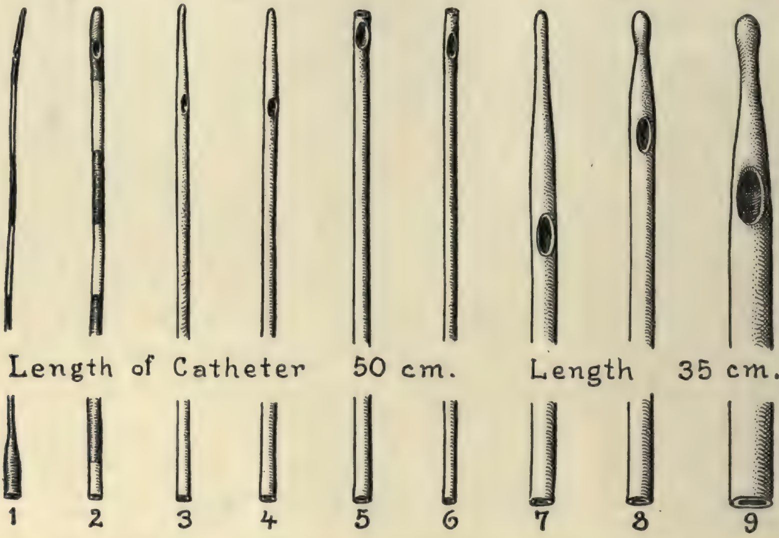


FIG. 140.—SERIES OF RENAL CATHETERS. Note different shaped ends and places of openings; 7, 8, and 9 are used for dilating ureteral strictures. Natural size.

ever, that the end of the stylet does not project from the eye during the introduction. The length of the catheter is from forty-five to fifty centimeters. They are, therefore, much shorter than those used in men. The sizes of catheters commonly used are 1½, 2, 2½, 3 mm. in diameter; occasionally a smaller catheter than 1½ is used, and, in treating strictured ureters, catheters may also be used that are 3½, 4, and 5 mm., or even larger in diameter. It is very important to use catheters with correctly made points and eyes. A slightly blunted, conical point (Fig. 140) is most satisfactory for general use, while the obtuse, blunter point (Fig. 140) is also occasionally useful, the blunt-ended catheter not being so liable to bend. The eye of the catheter should be wide open to give free access to the lumen, and the lumen of the best made catheters is very large, contrasting markedly with the tiny lumen of inferior makes. It is well to sterilize every catheter with a little snugly fitting rubber sleeve which projects about three centimeters beyond the outer end (Fig. 118). Avoid a catheter having a little bulbous tip with a

narrow neck behind it. The trouble with these is that the tip bends so easily that the catheter soon breaks. Also avoid one with a sharp needle-like point, as this is liable to impinge upon and injure the pelvis of the kidney.

When Catheterization Is a Safe Procedure.—It is safe to catheterize the ureter when the bladder is perfectly sound. If the instruments are properly

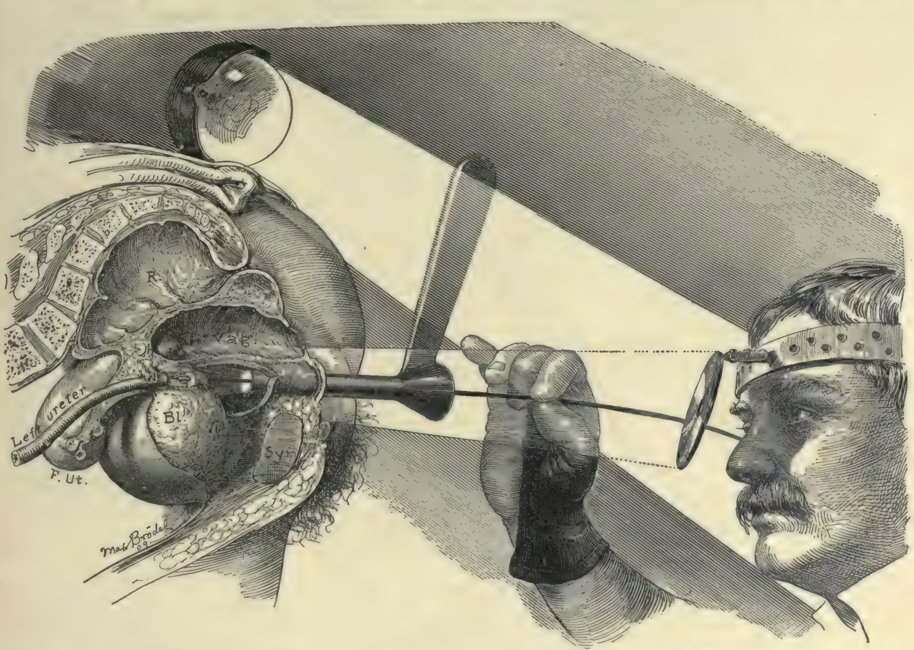


FIG. 141.—BEGINNING CATHETERIZATION OF THE LEFT URETER IN KNEE-CHEST POSTURE THROUGH OPEN-AIR CYSTOSCOPE. Note sterile half-glove on hand holding catheter.

sterilized no harm can possibly arise from a simple catheterization, provided due care is used when the catheter reaches the renal pelvis not to apply sufficient force to bruise the tissues and start hemorrhages. It is safe to catheterize the ureter when the bladder is diseased only in part. In such a case one can clean out the speculum and wipe off a normal ureteral orifice and pass up one of the smaller catheters without the slightest risk. It is also safe to catheterize the ureter when there is disease of the ureteral orifice, or when the escape of pus or blood shows that the kidney of that side is diseased. In such a case, in rare instances, undue force may bruise the renal pelvis and cause a chill, the so-called "ureteral fever," which runs its course in two or three days, perhaps with marked exacerbations and remissions. It is often a good plan in

these cases to give ten grains of urotropin four times a day for one or two days before and a day or two following the catheterization.

It is not safe to catheterize the ureter when a normal ureteral orifice is situated in the midst of an extensive vesical inflammation, or when the catheterization is difficult because of the contraction of the bladder and a more or less universal cystitis. Such infections are often only awaiting an opportunity to invade the upper urinary tract to terminate in pyelitis and surgical kidney, and any trauma and any instrumental opening up of the ureteral orifice serves but to invite the infection.

Technique of Catheterization.—It is our habit in catheterizing ureters in

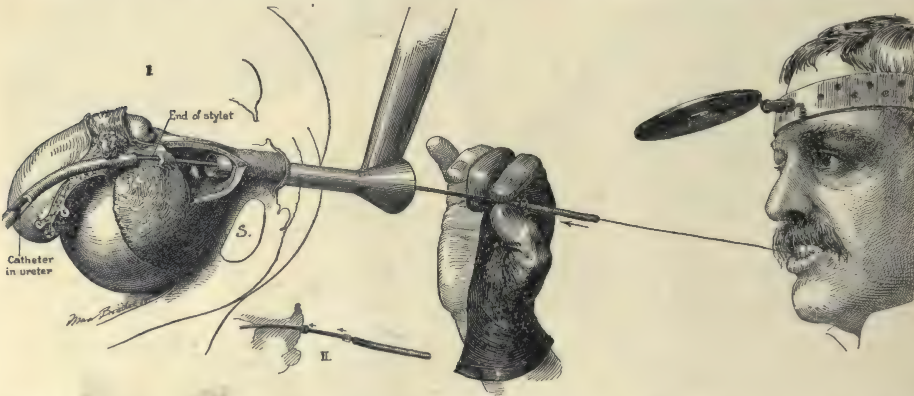


FIG. 142.—SECOND STEP IN CATHETERIZATION OF URETER. The stylet is held fixed by the teeth, its other end being in the intramural part of ureter. The catheter is stripped off the stylet with the gloved hand. Figure II shows small rubber cuff, pushed along catheter to external urethral orifice after withdrawal of speculum.

practically all cases to wax the catheter tip before its introduction. The wax on the end of the catheter serves the purpose of a tell-tale, revealing the presence of any stone encountered by it in its passage up the urinary tract. If the catheter is a little worn the wax, too, often serves to prolong its life by giving it a snug coat, not an unimportant matter considering the expense of these delicate instruments. The wax used is dental wax and olive oil in equal parts, a little more or less of the dental wax, according as it is harder or softer. This is sterilized by boiling and then kept in small, open-mouthed bottles and heated until it is liquid, when the point of the catheter is dipped in, taking care not to immerse the eye. On removing the catheter the wax quickly hardens, leaving a glistening surface, sensitive to contact with any hard body (Chap. XX). To catheterize the ureter the operator kneels, directing the speculum toward

the orifice, which has been discovered, and which now lies in full view under good illumination from the head-mirror. Then, holding out three fingers of the right hand, if he is to catheterize the left ureter, or the left hand if he wishes to catheterize the right ureter, an assistant draws over the fingers a sterile half glove or rubber finger-stalls. This avoids contaminating the sterilized catheter. The next step is for the assistant to hand him one of the ureteral catheters for ordinary purposes, such as collecting urine, that is, one measuring 1½-2 mm. in diameter. If he desires to obturate the ureter to prevent any reflux of urine he must take a catheter 2-2½ mm. in diameter, preferably one 2 mm. in size. Now, with one continuous movement, resting the catheter on the outer margin of the cylinder of the vesical speculum (Fig. 141), he carries it on up the lumen without touching its sides, engages it in the ureteral orifice, and pushes it on up for three or four centimeters (Fig 142). If several to and fro movements are made in the effort to engage the

FIG. 143.—SAME VIEW OF THE BLADDER AS IN FIGURE 136. Left side catheterized. Speculum removed and reintroduced. Catheterization of right side begun.

catheter there is a likelihood of gouging or scratching the wax and then of mistaking this artificial marking for one produced by a stone.

The next step is to take hold of the outer end of the stylet which projects beyond the rubber sleeve, grasping it with the teeth while the catheter is slowly and cautiously, inch by inch, pushed on up the ureter. After about twenty centimeters of the catheter has passed up, the glove is taken off to aid the

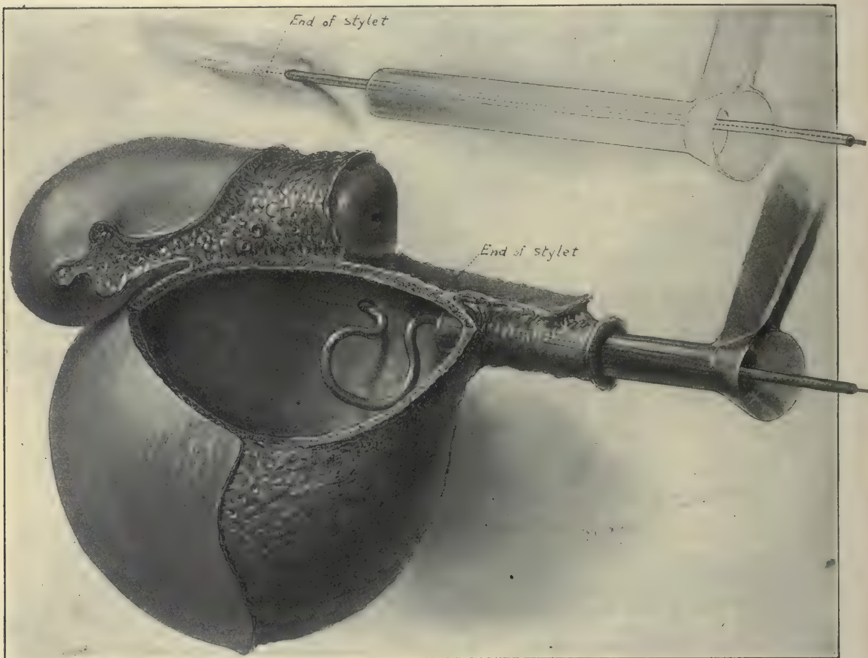


FIG. 144.—CORRECT POSITION OF STYLET IN CATHETERIZING URETER (upper figure). This should be so that point enters the ureter. Lower figure shows curled up catheter in bladder due to failure to observe this precaution.

tactile sense, and the catheter is then pushed up more slowly and more cautiously, feeling the way until a slight, general, almost imperceptible, but still distinguishable, resistance is felt. The catheter has then touched the top of the renal pelvis and no more force must be used. If both sides are to be catheterized, the stylet may be pushed in a little distance, so as to pass on up the catheter into the ureter, after which the speculum is withdrawn and reinserted. It is often better to take a speculum $\frac{1}{2}$ mm. smaller in diameter, that is, after using a No. 10 speculum to use a $9\frac{1}{2}$ (Fig. 143). This is introduced through the urethra into the bladder, leaving the ureteral catheter outside, that

is to say, between the urethra and the cylinder of the speculum. The opposite ureteral orifice, which in all cases has been sought out beforehand, so that the examiner is familiar with its position and characteristics, is then looked for and the catheter introduced in like manner. In withdrawing the speculum the second time one must take care to avoid pulling out either of the catheters, especially the one first introduced. This is done by holding them firmly in the hand until the speculum is freed from the urethra. When the stylet does not reach all the way to the ureteral orifice, a kinking of the catheter occurs, with failure to enter the ureter, as shown in Figure 144.

The speculum is now laid aside and the patient assisted to turn to one side. If one kidney is catheterized she should lie so as to bring the catheterized side uppermost. The sleeve is now cautiously pulled off the end of the catheter and the end is inserted in a sterilized glass tube, plugged with cotton and set in a block of wood (see Fig. 156) to catch the urine as it flows down from the kidney; it is convenient to have the patient lie on a board, like the common lap-board used in sewing, if she has been catheterized on a bed. Inasmuch as the catheter is sterile and the glass collecting tube is also sterile and plugged with sterile cotton, the urine gathered in this way may be examined for its bacteriological contents, as well as for microscopic and chemical elements. For the purpose of ordinary examination from three to five c. c. of urine are sufficient. If the kidney is active, or if its action is quickened by taking fluid beforehand, or in a nervous patient suffering from polyuria, the flow begins within a few seconds after the withdrawal of the obturator. In a normal kidney the urine comes down by little spurts, three to five drops following one another in rapid succession, followed by an interval of rest from fifteen to twenty seconds, when the flow begins again. As a rule a droplet appears at the end of the catheter, hesitates a little, and may at first be drawn back by the inspiratory process of the patient, and then is forced out again; it is followed by another drop, then with increasing rapidity by several drops more, then the movement slows up again. In this way a normal kidney presents an appearance of activity which is best described by the word "lively." The contraction of the renal pelvis is an active one, is rhythmical and punctuated by staccato movements. The activity of such a kidney is in striking contrast to that of a hydronephrotic kidney with a flaccid pelvis, where the dropping is never staccato, but is a dull, lazy, lifeless drip. The average rate of secretion of the two kidneys is one and a half liters (three pints) per diem, which is one-half of a c. c. for each kidney, and with surprising frequency the rate of secretion, as measured at the time of catheterization, closely approximates this amount. In order to get larger amounts of urine, for the purpose of testing the relative activities of the two kidneys or

the activities of both sides under stimulation, one can safely leave the catheters *in situ* for a half hour, an hour, or several hours. In cases of disease the catheter can be left in for several days, or, as in one of our patients, for several weeks.

Value of the Transvesical Specimen of Urine.—It is often unnecessary to catheterize both kidneys in order to secure separated urines representing the respective kidneys. If the ureter of one side is catheterized the urine flowing from the pelvis of the kidney down through the catheter through the bladder and urethra into the receptacle on the outside will, of course, perfectly represent the secretion of that kidney without further modification than occurs in entering the pelvis of the kidney, where it is received into the catheter through the eye. If now for any reason it is not advisable to pass a catheter up the other ureter, so as to separate the urine of the remaining side in the same way, a perfectly satisfactory specimen can often be secured by simply putting an ordinary vesical catheter through the urethra in the bladder and collecting the urine from the opposite side in this way. Two things are of importance in connection with this transvesical urine: In the first place the bladder ought to be emptied of all its mixed urine. This should be carefully done with the evacuator, just before proceeding to catheterize the ureter. In the second place, if the bladder is inflamed or ulcerated, the urine from the opposite side taken transvesically may be contaminated. As a matter of fact, this objection is practically of little weight, as the urine escaping from the ureter seems to pass at once by the shortest channel to the eye of the catheter and out into the receptacle, so that, even in the case of a badly inflamed bladder, the contamination is surprisingly little and is readily allowed for in the subsequent microscopic and bacteriological examination. Even when the urine is thus contaminated, the specimen secured in this way is always available for a urea determination, which is, as a rule, the important factor in the case. For example, suppose we have catheterized a bad kidney on the left side and, being unwilling to risk catheterizing the presumably good right kidney on account of an extensively inflamed bladder, we determine to collect the urine from the right kidney transvesically, we are at the same time securing that from the left by the ureteral catheter.

Having carefully noted the condition of the bladder, emptied it completely, and maybe irrigated it in order to cleanse it as far as possible, the patient is placed in the dorsal position for, say, half an hour, with the ureteral and vesical catheters in separate receptacles. The urine from the ureteral catheter is measured, noting the amount collected each five minutes of the period. The urine from the vesical catheter is collected in like manner, taking precaution

to throw away the specimen obtained during the first five or ten minutes. In such a case the examination might read as follows: Left kidney catheterized per ureteral catheter, urine contains much pus, low specific gravity, urea 0.8 per cent. The report on the specimen of urine by the vesical catheter might read: Urine contains a few pus cells, probable contamination from bladder, specific gravity normal, urea 2 per cent. In this case a surgeon would be fully justified in proceeding with the operation upon the diseased left kidney on the basis of the findings in the transvesical specimen. Again, in another case it may be impossible to introduce the ureteral catheter into the diseased side, owing to a stricture or an obstruction; or the diseased orifice may be lost in a mass of ulcerating tissues, while the normal orifice may be found in the midst of sound tissue. In such a case, after wiping out the speculum with a pledget of cotton, saturated with a 1 per cent. solution of nitrate of silver, and wiping off the orifice of the ureter seen through the speculum, the examiner then catheterizes the sound side and collects the urine transvesically from the diseased one. In such cases the findings, which are almost always striking, may show a marked difference, the transvesical specimen containing little urea and much pus, while the ureteral catheter delivers urine from the sound side. Not infrequently, while the urine flows freely from the sound side, no urine at all is delivered through the vesical catheter, showing a dead kidney or at least some obstruction in the urinary tract.

In all these cases the examiner is greatly assisted by having at hand a specimen of the mixed urines. He will often arrive at a very correct determination of one side by taking the mixed urines and the urine drawn by ureteral catheter from one side and examining both carefully and then deducting from the mixed urines the one side known, so as to infer the condition of the opposite side. Take, for example, the simplest case, namely, that of determining the specific gravity of the opposite side. Let us represent the specific gravity of the mixed urines obtained from both sides by the letter *S*, the specific gravity of the right side by *R*, and the specific gravity of the left side by *L*. We have then:

$$S = \frac{R + L}{2}; \quad \text{or} \quad 2S = R + L.$$

Now *S* being known and *L* being known, it is easy to get *R* out of this formula, or, *S* and *R* being known, it is easy to derive *L*. The same is true in making a determination of urea. It is important in making such estimations by formula to get the mixed urines and the urine from one side approximately at the same time.

Uses of Ureteral Catheterization.—This is of value under the following conditions:

(1) In demonstrating abnormal constituents in the urine, such as pus, blood, gas, bits of stone, microörganisms, which may be absent on one side while present on the other, or may be present in large amounts on one side and very slightly on the opposite side.

(2) It is capable of determining impaired function on one side, as shown by the diminished excretion of urea and by polyuria.

(3) It may show impaired function on one side by failure to respond to stimulus.

(4) It may also show that one side is entirely dead; that is, incapable of secreting any urea whatever.

(5) It demonstrates impairment of one side by the slow way in which the kidney of that side responds to the color test (the injection of indigo-carmin into the tissues).

(6) The presence of hydronephrosis or pyonephrosis is shown.

(7) It gives the size of a hydronephrosis or a pyonephrosis by enabling the examiner to inject fluid until the maximum distention of the pelvis of the kidney is reached, and he can measure the amount of fluid withdrawn by the catheter from the pelvis of the kidney, thus accurately determining the capacity of the sac.

(8) The wax-tipped ureteral catheter demonstrates the presence of a stone in the ureter or in the kidney by the scratch marks made on the sensitive, highly polished surface.

(9) By the injection of fluid into the kidney until the renal pelvis is fully distended, the ureteral catheter enables us to bring on an artificial renal colic at once, which can be identified or distinguished from an obscure pain felt in the side whose habitat up to this examination has been unknown.

(10) It is valuable as a means of treating the pelvis of the kidney by injections and irrigations for pyelitis.

(11) It may be the means of starting the secretion of the kidney by injecting and washing out the pelvis.

(12) It may be used to make a channel for the escape of urine when the ureter is obstructed by cancer or a tumor.

(13) We are enabled to locate the exact position of a stricture of the ureter, and by means of a spring balance to determine the strength of the bite of a stricture.

(14) It affords a means of dilating some ureteral strictures.

(15) We can measure the length of the ureter plus the renal pelvis from the vesical orifice up.

(16) By means of the ureteral catheter loaded with graphite or other substance impervious to the X-ray, phleboliths and calcareous concretions outside the ureter can be distinguished from ureteral stones on the X-ray plate.

(17) By its means the renal pelvis and the ureter can be injected with a fluid impervious to the X-ray, and the location and size of the pelvis of the kidney and ureter can be determined by the X-ray.

(18) The curve at the end of the ureteral catheter sometimes gives us a fair idea of the size of an enlarged renal pelvis, as the catheter when taken out and laid immediately on a cold surface assumes approximately the form it had in the body (Fig. 132).

CYSTOSCOPES.

Modifications of the Kelly Cystoscope.—It would be incomplete to close this chapter without reference to some modifications of the Kelly cystoscope, which are much used, and, in certain hands, have given the greatest satisfaction. We have faithfully used many of these and attempted a number of our own, but must confess that in the end we have always reverted to the instruments described in this chapter. It is possible to work satisfactorily with these modifications, but they do not afford greater ease in the examination, and, in our experience, do not show superiority in the way claimed for them; on the contrary, they possess disadvantages in the way of greater cost, less adaptability to thorough sterilization, and greater caliber to secure the same field of vision. In addition to the great increase in primary cost, the upkeep of these instruments is greater, and they must constantly be watched in order to ensure their perfect order. These objections certainly hold true so far as cystoscopy in the female is concerned. In the male, on the other hand, they have (notably the instrument of Luys) certain advantages, arising from the fact that the knee-breast posture, the ideal one to use the Kelly cystoscope in, is rather trying on the male subject. In our experience the elevated dorsal posture does not give such good dilatation as the knee-breast position, and, furthermore, the field of vision is being constantly obscured by the urine when catheterization of the ureter is attempted. Under such circumstances a continuous aspiration of the bladder contents is advantageous. The first catheterization of the ureter in a man, through an open-air cystoscope, was carried out by Kelly and reported in the *Ann. Surg.*, 1898, xxvii, 475. He used a cystoscope modeled exactly upon his female cystoscope, but about 16 cm. long. It is often difficult

to introduce a straight tube into the male bladder. This is readily obviated by the use of an obturator of which the beak can be bent to any angle desired by means of a screw at the external or handle end of the obturator. This kind of an obturator and the long cystoscope are shown in Figure 145. This type of obturator was introduced by Luys and has been modified for the Kelly instrument by Burnam. It can readily be introduced in the knee-breast posture, and the trigonum, neck of the bladder, and posterior wall easily examined. Catheterization of the ureters is likewise fairly easily executed.

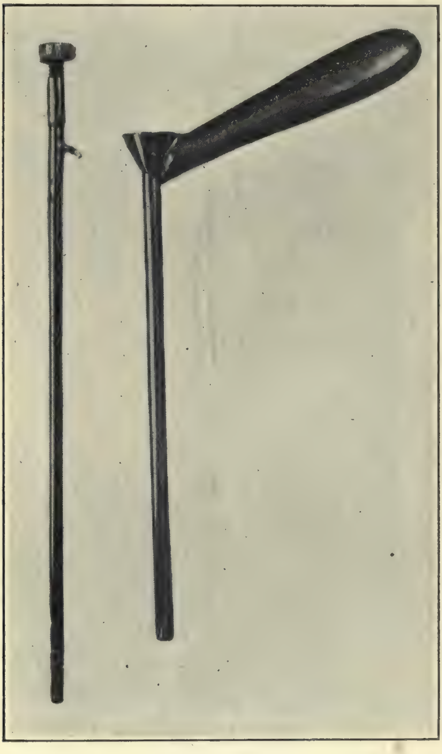


Fig. 145.—A Modification of Kelly's Cystoscope, Adapted for the Male. After introducing the plunger by means of the screw, it is possible to have a straight or beaked instrument.

The chief divergencies of these instruments from the Kelly model consist in replacing the head-mirror illumination by an electric illumination in the interior of the bladder, and in the attachment of an apparatus for continuous aspiration of urine. In addition, in some instruments, the handle is left off and Luys has added a magnifying glass placed at the outer end of the cystoscope. Unless a beak be added to the cystoscope, which allows a large lamp to be used, we do not find the illumination can be increased. The small detachable lamps on a special holder, such as are used in the Valentine endoscope and Luys cystoscope, do not, as a rule, give as good an illumination as is attainable by the reflection of a strong light. The disadvantages of a beak are particularly noticeable in those cases which we especially desire to examine cystoscopically, namely, in diseased bladders. Although by the use of cold lamps all danger of burning is removed, nevertheless, the contact of the beak with the wall constantly causes irritation, and it is almost impossible to view the bladder and avoid this contact.

The continuous aspiration first employed by Garceau on an ordinary Kelly

type of cystoscope adds to the apparatus and is not in the least necessary in the knee-breast posture. We are rarely troubled with the accumulation of urine in the bladder.

The handle is of great advantage in female cystoscopy, but can readily be done away with in the male. A magnifying glass does not give a greater field

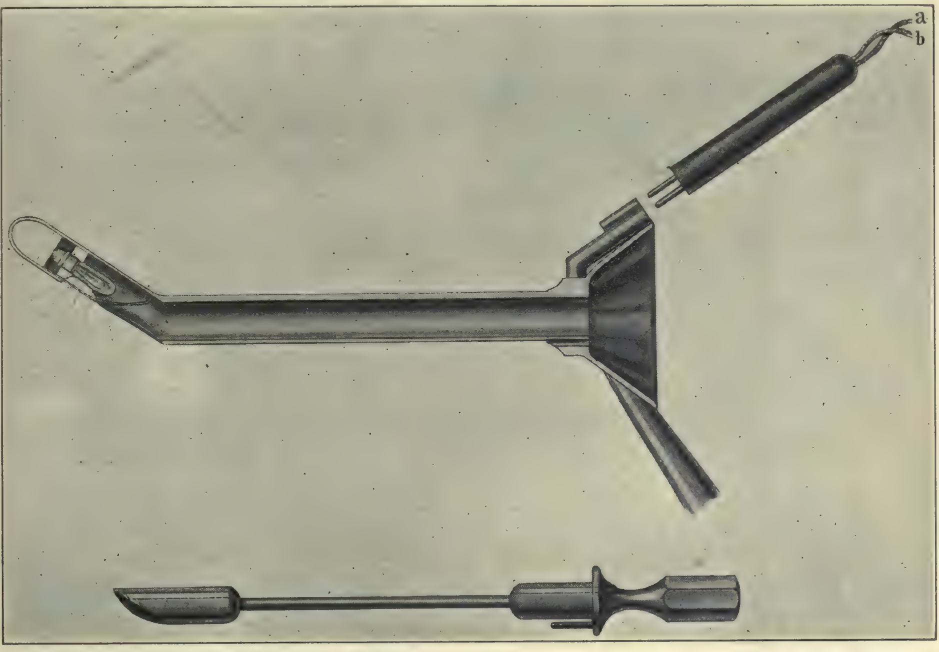


FIG. 146.—CULLEN'S OPEN-AIR ELECTRICAL CYSTOSCOPE. The lamp is a cold one.

of vision, and, with the naked eye, details of the surface of the interior of the bladder can be readily observed and studied.

We will refer here to only two of these models, the Cullen and the Luys, because they give in principle what is found in all.

The Cullen Cystoscope.—This instrument, manufactured by the Rochester Surgical and Electrical Instrument Company, was designed by Dr. Thomas S. Cullen, and described in the *Johns Hop. Bull.,* 1903, xiv, 166. Its structure is readily appreciated by observing Figure 146. It is a Kelly instrument with a beak added, containing a small, cold electrical lamp, this being lighted by two delicate wires running along the lower part of the barrel of the cystoscope, or by connecting the attachment upon the handle of the cystoscope with an

electric battery by cords; where electricity is at hand it is more convenient to use a transformer, as shown in Figure 147. This particular instrument was designed for examining female bladders. It can be made of any caliber desired, but, in order to secure a good view, should at least correspond to a Kelly, No. 10, cystoscope. It has the disadvantages already pointed out in a beaked instrument and it furthermore gives to the trigonum region of the bladder a deep purplish color, which renders the diagnosis of inflammation there very difficult. It cannot, like all straight tube, be used as an endoscope for the urethra.

Fig. 147.—A Small, Very Convenient, Universal Transformer of Electric Current. It is screwed into the socket of any electric light fixture and transforms any kind of current to one suitable for cystoscope.

Luys Cystoscope.—This instrument, pictured in Figure 148, is made in two forms: An instrument at least 18 cm. long, and with a caliber of 23 French, to be used in examining male bladders; and another, shorter instrument, 10 cm. long and of greater caliber, for use in the female. As a rule it causes a good deal of pain but can readily be used with anesthesia, as we have shown in several cases. In the lower wall of the barrel of the tube is a small fixed canal which serves as an aspirator. It is connected with a suction apparatus continuously working. Along the upper wall is a small groove into which the thin piece of metal tubing carrying the electric wires is inserted, and at its end a very small cold Edison lamp is introduced. The application of the electric current to the lamp is exactly as in other forms of an electric cystoscope. Connected with the handle of this lamp carrier is a little magnifying glass with a focal length corresponding to the length of the cystoscope. At its base is the usual make and break switch for cutting off or putting on the current to the lamp.

Luys makes all of his examinations in the elevated dorsal posture, and succeeds admirably in examining both men and women. In the same way as with the Kelly cystoscope, he has performed numerous operative procedures in the bladder. In catheterizing the ureters he employs a styletted instrument and can readily use the wax-tip catheter in the male. Luys holds this method to possess great superiority over the water cystoscopes in the male as in the female, excluding only those cases, sometimes met with in adults and always in children, in which there is a very small calibered urethra.

To Dr. Luys is certainly due the credit for carrying out cystoscopy of the male bladder with the direct air cystoscope in a large number of cases, and of demonstrating the feasibility and advantages of this method as a practical routine measure.

He began his work in 1902, and a full description and explanation of the method are given in his book, "L'exploration de l'appareil urinaire," Paris, 1907.

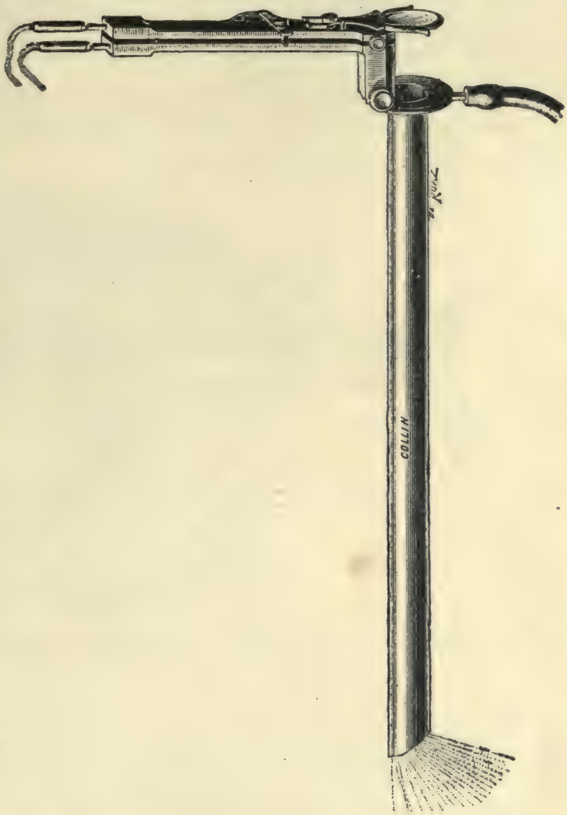


FIG. 148.—LUYS' DIRECT VISION CYSTOSCOPE.

From a limited experience with males we are inclined to believe that, for general work, the prism type of cystoscope with water dilatation of the bladder is superior to air cystoscopy as a routine measure. In both men and women great corpulency is a strong contraindication to aërocystoscopy. It is very difficult for these patients to take the necessary posture and, as a consequence, dilatation of the bladder is imperfect.

We are perfectly convinced of the superiority of the air method in women, and base our conviction on the following facts:

(1) The aërocystoscopic method is a direct one, as, whether the examiner uses a head-light reflector, an electric light, or daylight, or introduces a little electric light into the bladder, he looks directly through the open tube at the vesical mucosa.

(2) The method is extremely simple, requiring only a little cylindrical speculum with a funnel-shaped orifice and a stout handle, and a head-mirror with an ordinary electric light.

(3) The instruments are inexpensive. Most physicians possess a head-

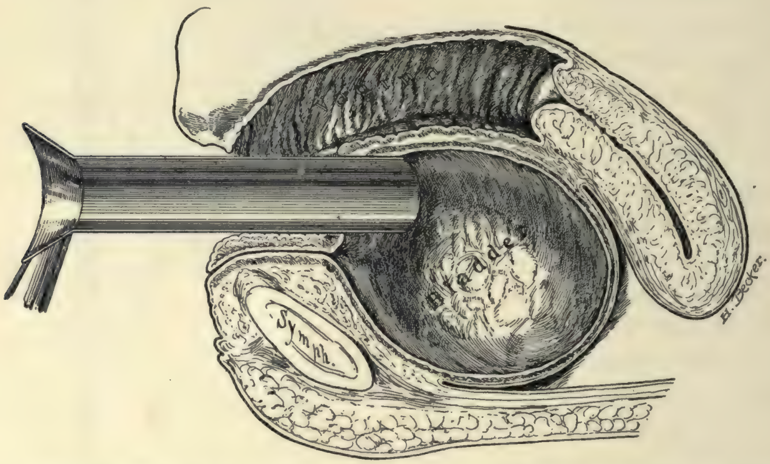


FIG. 149.—EXAMINATION OF BLADDER THROUGH A VESICO-VAGINAL FISTULA. Knee-breast posture. Note large size of speculum. (Mrs. J., 1901.)

mirror, and the speculum, the only essential instrument, costs but two or three dollars. A beginner can get along very well with one speculum.

(4) The instruments are just as durable as vaginal or rectal specula.

(5) The method is easily learned and requires no special training; after one or two demonstrations anyone can do it.

(6) All extensive and difficult transportation of electrical apparatus is avoided.

(7) Aërocystoscopy is always available on account of the simplicity of the technique.

(8) It is not necessary to expand the bladder with fluid (often exceedingly painful when bad inflammation exists).

(9) There is no leakage at the side of the instruments and no strangury in trying to empty the bladder.

(10) No turbid medium makes it necessary to spend a considerable time clearing out the bladder in trying to get a view of the vesical walls. Vision across an air medium is better than the clearest water.

(11) The method is vastly more rapid than the telescopic ones. Four or five patients can be examined by this method while one is being examined by the telescope.

(12) There is no danger of burning the base of the bladder near the neck, an accident which has happened many times with the telescopic speculum.

(13) Through the open-air speculum one can measure, touch, and treat the bladder walls.

(14) The ureters can be catheterized directly.

(15) The risk of infection in catheterizing ureters when the bladder is inflamed is greatly lessened.

(16) Catheters of various sizes, even up to 16 mm. in diameter, can be passed up the ureter.

(17) By passing up a large size the ureter can be obturated, preventing any reflux from the kidney, which gives the result of the examination of any specimens obtained from the bladder.

(18) Transvesical specimens can be readily secured by this method, impossible when the bladder is distended with fluid.

(19) By the aërocystoscopic method we can examine a badly inflamed bladder when it is impossible to do so with the telescope.

(20) It can be used when there is a hole in the bladder opening into the vagina or into the bowel, making it impossible to distend the bladder with fluid for the telescopic method (Fig. 149).

(21) As a rule abnormalities in the bladder, particularly in the way of extensive inflammation, at once increase the difficulties of the telescopic methods of examination, while these conditions add no special difficulty to the aërocystoscopic one.

CHAPTER X.

EXAMINATION OF THE URINARY TRACT BY MEANS OF THE NITZE TYPE OF CYSTOSCOPE.

The underlying principles of this type of cystoscopy are essentially different from that of the open-air method described in the last chapter. In the latter the distention of the bladder is secured by the posture of the patient, and the observer looks directly into the organ; in this type the bladder is distended, usually with some fluid, sometimes with a gas, and the observer views its interior through a system of lenses. The illumination is secured by an electric light in the end of the cystoscope which is in the bladder. Special instruments have been devised to meet special requirements and to carry out the various procedures of catheterizing the ureters, of operating intravesically, and of photographing the interior of the bladder.

We owe this instrument to Max Nitze, who first presented it to the profession in 1879. This original cystoscope was a very crude affair compared to the splendid instruments of to-day; nevertheless it gave excellent views of the interior of the bladder. The light was secured by the heating of a platinum wire to a white heat, which was kept from burning the bladder by constant irrigation with cool water.

It was not until 1886 that the development in electrical lighting permitted the replacement of this imperfect and dangerous method of lighting by the Edison lamp. Since that time the enormous advance in the methods of dealing with electricity and the improvement of optical instruments have permitted great improvements. The ingeniousness of instrument makers, brought to the aid of urologists, has overcome one obstacle after another until instruments have been secured which permit easy inspection of the bladder, catheterizations of the ureters, and many other manipulations of the bladder toward the aid of treatment as well as diagnosis. Nitze himself took part in most of this development, and lived to see his instrument, which at first was regarded merely as a plaything, become almost an indispensable part of the armamentarium of every urologist. Catheterization of the ureters in the male was first suc-

cessfully carried out by James Brown (*Bull. Johns Hopkins Hosp.*, 1893, iv, 73), who used a Brenner cystoscope. Brenner himself had catheterized the ureters in the female some time previous to this. Catheterization with this instrument corresponds to the direct catheterization by means of the Bransford Lewis instrument, and at the present time is used more with women than men. The first really successful appliance for catheterizing by the indirect or prism method was devised by Albarran (*Rev. de gyn. et de hyg. abdom.*, 1897, i, 457). At the present day the cystoscopes are of two types: the first, the Nitze type, has the optical apparatus, the sheath, the light, the catheterizing part, all in one piece; the second has the catheter and the light in one piece, and the optical parts in separate pieces, which fit into the sheath. The most complete instrument of this latter type is that of Bransford Lewis of St. Louis. The originator of this type of cystoscope was Boisseau du Rocher, who described his instrument in the *Ann. d. mal. d. org. génito-urin.*, 1890, xviii, 65. For purposes of asepsis, manifold use, convenience, and completeness, this type of cystoscope is rapidly replacing the older Nitze form. The Brown-Buerger is another splendid form of this cystoscope. Among foreign cystoscopes, working toward the same type, are those of Kollman and Baer. Instruments of this kind, which afford a number of lenses with the same sheath, do away with necessity of apparatus; such, for example, as the Schlaginweit, which allowed an alteration in the position of the prism for seeing different parts of the bladder.

The ideal cystoscope is one which gives a clear view of all parts of the bladder. (This is only afforded by the universal cystoscopes, such as that of Lewis.) It should furthermore be so equipped that the bladder can be thoroughly and rapidly irrigated, and, if need be, a continuous irrigation carried on during the examination. It should be provided with a catheterizing apparatus permitting double catheterizing and the use of large catheters. Furthermore, it should be so constructed that the instrument can be withdrawn and the catheters left in place in the ureters. It should have parts for doing intravesical operation. These various advantages can be combined in a single universal cystoscope, which not only means less expense to the physician, who has to purchase, but is a great saving to the patient, as frequently, especially in the male, the introduction of the cystoscope is the most disagreeable part of the whole examination, and by the universal cystoscope one sitting and one introduction may suffice for all parts of the examination.

In order to learn the use of the cystoscope, it is essential, in the first place, to understand the construction of the instrument. So far as the optical ap-

paratus is concerned, all cystoscopes are built on the Nitze plan. We will, therefore, give in some detail the description of this type.

THE SIMPLE NITZE CYSTOSCOPE FOR BLADDER EXAMINATION.

Structure.—The instrument consists of three parts: the ocular end, the shaft, and the beak (Figs. 150 and 151). The ocular funnel-shaped end of the cystoscope contains a lens which magnifies the image obtained through the system of lenses. The site of the objective in the cystoscope, in this case a prism, is shown by the little knob on the rim of the ocular. By observing this the operator knows just what position the cystoscope is in after its introduction into the bladder. On this ocular end is also the connection between the electric wiring of the cystoscope and of the cable which conducts the electricity from its source to the instrument. The two wires end in two metal rings, which are separated and isolated by hard rubber. On the metal ending of the cable is a little sliding piece of metal which allows the making and breaking of the current.

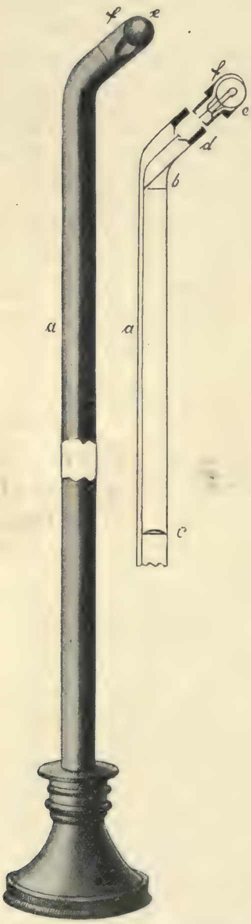


FIG. 150.—THE FIRST MODEL OF THE NITZE CYSTOSCOPE.

The shaft of the cystoscope is about 21 French in diameter and resembles the ordinary metal catheter. This shaft contains the electric wiring, three plano-convex lenses, and a prism placed as shown. The electric wiring ends in a small platinum plate. The beak is a blunt, short projection from the shaft at an angle of about 45 degrees. It has a smooth, rounded end and can be screwed directly on the shaft. It carries the little electric lamp of the ordinary Edison type. In the more recent cystoscopes the Edison type of lamp is replaced by the cold lamp. With the lamp in place there is a direct communication between the source of electricity and the lamp. As already stated, the usual caliber of the cystoscope is 21 French; this has been reduced to much smaller size for examining children, and a larger and shorter instrument can be used in examining women.

Optical Principles of the Cystoscope.—THE LENSES.—The optical system of the Nitze cystoscope, which can be taken as a type, is shown in Figure 150. It is simpler for purposes of understanding to consider the lenses apart from the prism. As will be shown, the prism acts exactly as a mirror and transfers the image of the bladder through the lens system. These lenses accomplish the following optical effects: first, the closer the object is to the end of the cystoscope the greater its magnifications, and the farther away, the smaller its magnifications; second, an object close to the lens and highly magnified

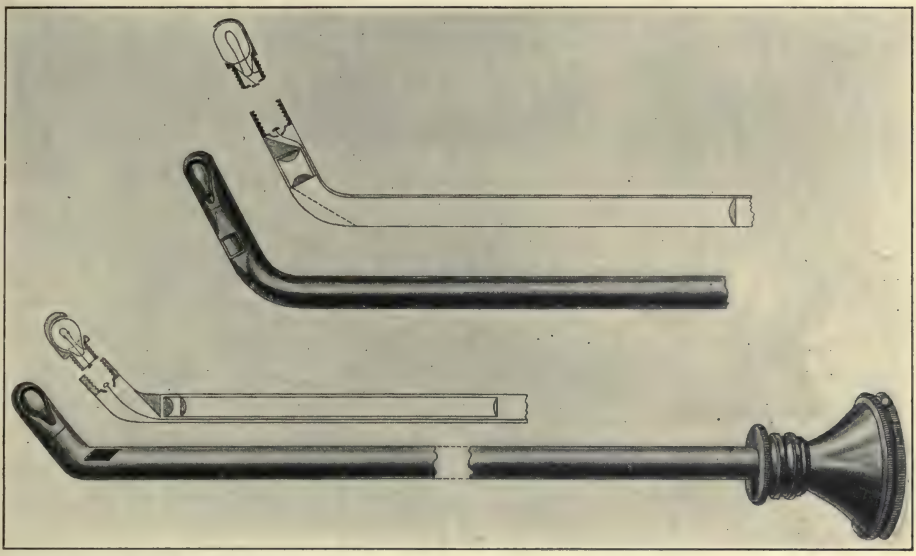


FIG. 151.—NITZE CYSTOSCOPE. Showing ocular position of lenses in tube, the prism, the beak with Mignon light. This is the type of all modern electrical cystoscopes.

can only be seen in part, and the further away the object, the greater the amount of it that can be seen. These facts rest upon the principle that the cystoscope can ordinarily take in only the field of an angle of from 70 to 80 degrees. For instance, we all recognize that by this angle of measurement the finger held close to the eye may be taller than a church steeple a short distance away. At a distance of about 3 cm. from the optical part of a cystoscope an object will seem natural size. At a greater distance it is smaller than natural, and closer it is larger. The two plano-convex lenses situated near the beak end of the shaft make a real upside-down image of the object looked at. In the middle of the shaft there is a second convex lens which brings the image to the ocular

end of the cystoscope. The image at this point is right side up, and is enlarged by the ocular lens. In a cystoscope where only lenses were employed, the resulting image would be right side up. Such a system is present in the Brenner and certain parts of all the universal cystoscopes. In such an arrangement the observer looks directly through the cystoscope. Such an apparatus is of use in observing the posterior wall of the bladder and the trigonum. In the male it is impossible to see with it all parts of the bladder. This can, however, be fairly well accomplished in the female.

The Prism.—The prism shown in Figure 150 has the effect of turning the picture at a right angle. The prism itself is a right-angle prism, one side fitting in the window in the side of the shaft, and the other lying at a right angle to this. The hypotenuse of the prism lies obliquely. The action of the prism is exactly like that of a mirror, in that it gives an upside-down view. Its effects can be readily studied by taking an ordinary mirror placed at a similar angle and studying the appearance of the object itself and its reflection in the mirror. Objects in front in reality, appear behind in the mirror; and objects really behind, seem to be in front. On the other hand, there is no reversing of right and left. Objects in the right part of the field remain in the right, and objects in the left remain in the left. The effect of this turning can be appreciated if one imagines that his eye is in the prism of the cystoscope. In addition to this reversing there is a distortion when objects not directly under, but lateral to the prism are observed. By turning the beak of the cystoscope to an angle of 90 degrees the lines on a page are turned to an angle of 180 degrees. The ureteral orifice can be observed in this way, and its axis be made to turn.

Bearing in mind all these optical peculiarities, it is easy to understand how the beginner can readily become confused as to the location of different parts of the bladder. He likewise may readily mistake the size of objects. In almost any cystoscopic picture some parts of the field are closer and therefore much more magnified than others. Theoretical explanations of the optical apparatus, however, lead the beginner to the conclusion that the interpretations are much more difficult than they really are. They can be readily learned and are best learned by a little practice with actual cystoscopic examinations on the outside of the body.

Some of the newer cystoscopes have introduced into the ocular end a second prism which reverses the image once again and gives a view of the bladder in its normal relations. Small apparatus containing this second prism can be secured and placed on any cystoscope, with the result that the image is right

side up. This is a very practical addition, and, though it cuts off some light, will probably ultimately be added to all cystoscopes.[1]

OTHER FORMS OF CYSTOSCOPES.

None of these modifications are necessary for a complete observation of the female bladder, as the short urethra permits the turning of the cystoscope at so many angles, but in the male the common type is not good for examining the posterior wall and the sphincter region. Nitze has made two models to meet these two purposes. These are met, likewise, in the universal cystoscopes. Schlaginweit has an instrument in which the prism can be slightly turned so as to meet the various needs in examination of the entire bladder with a single instrument and at a single sitting.

The ideal conditions for cystoscopy can not, however, be met by a purely optical instrument alone. It is necessary that the fluid filling the bladder be transparent. This form of cystoscopy can be carried out in an air-distended bladder, but for the most part is practiced in water-distended bladders. Under perfectly normal conditions the ordinary Nitze instrument suffices. When, however, the presence of pus or blood renders the fluid in the bladder turbid, it must be removed. To provide for this removal the cystoscope should be so constructed that a thorough irrigation can be carried out with the instrument in place. This is a feature met with in all modern cystoscopes. Note the arrangement in the Kollman, the Brown-Buerger, and the Bransford Lewis (Figs. 153, 154, and 155).

The Braasch Cystoscope.—Dr. Wm. Braasch of Rochester, Minn., has ingeniously embodied the principles of direct cystoscopy without lenses and water-distention of the bladder. His instrument consists of a straight open barrel, carrying wires to a small electric light in a beaked end, similar to all the electrocystoscopes. Before introducing the cystoscope, an obturator, similar to that employed in the Kelly speculum, is put in. When the cystoscope is inserted in the bladder, the obturator is removed, and a small glass window inserted into the eye end of the instrument. Light taps on the barrel admit of the easy introduction of water into the bladder and of continuous irrigation, when necessary. There are also various catheterizing and operating attachments. The observer looks through the barrel of the cystoscope, which is filled with water. The instrument can be used for either male or female, and in Dr. Braasch's hands is a perfectly serviceable one, though the field of vision afforded is small,

[1] Legueu. F., "Traité chirurgical d'urologie," p. 95.

and in the female it is, in our opinion, inferior to the open speculum. The disadvantages of the knee-breast posture are more imaginary than real.

CATHETERIZING CYSTOSCOPES.

Two general types of catheterizing instruments are met with: those of the Brenner type and those of the Albarran type. In the universal cystoscope both of these apparatus may be employed.

Brenner Type of Catheterizing Cystoscope.—In this type there is no prism. The observer looks directly through the barrel of the cystoscope. In the lower part of the barrel is a tube that carries the catheter, which in this case is pushed into the ureteral orifice just as by the direct aërocystoscopic method. A stylet is of distinct advantage.

Albarran Type of Catheterizing Cystoscope.—The catheterization is carried out with a cystoscope containing prisms. In order to direct the catheters into the ureters a catheter lifter is placed just in front of the prism. This lifter is controlled by screws at the ocular end of the cystoscope. By lifting it, the point of the catheter can be raised to any desired angle up to a right angle and guided into the ureter. This lifter is shown in the Nitze, the Bransford Lewis, and the Brown-Buerger cystoscopes shown in Figures 151, 154, and 155.

OPERATIVE CYSTOSCOPES.

Nitze, Casper, and Bierhoff have all introduced appliances which permit of the removal of benign tumors, the crushing of stones, and the removal of foreign bodies from the bladder under the guidance of the cystoscope. Dr. George Walker, of Baltimore, reported in the *Ann. Surg.*, 1907, xlvi, 452, a very ingenious combination of lithotrite and cystoscope by means of which small and medium-sized stones can be grasped and crushed. The additional instruments consist of snares, which can be used to reach any part of the bladder, and are heated by the electric current; galvanic cautery knives have also been added. The pan-cystoscope of Baer (Fig. 152) is provided with a splendid outfit of this kind. Nitze has demonstrated beyond all question that instruments of this kind can be successfully used in the bladder for operative purposes, as well as the open-air cystoscopes. He and others have secured quite brilliant results. The cystoscopes of this type must be thoroughly studied before using them and this can only be done in a clinic where they are being

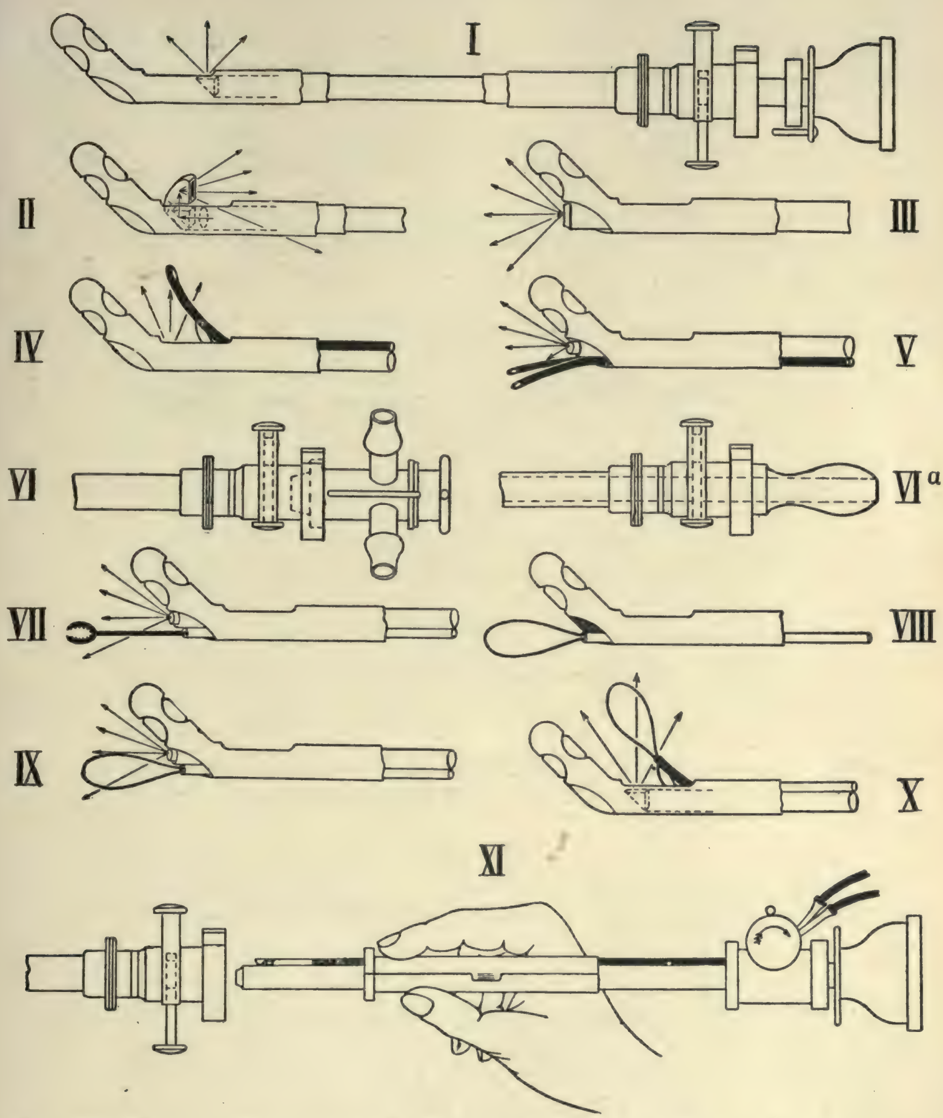


FIG. 152.—PANOPTIC CYSTOSCOPE. I, sheath with Nitze optic inside it; II, sheath with Schlaginweit's optical apparatus; III, sheath and direct vision part; IV, small optic with ureteral catheter; V, direct catheterizing part; VI, shows the two-way irrigation apparatus of the sheath; VII, direct vision with a small forceps; VIII, a snare; IX, snare with small direct vision telescope; X, snare with indirect vision cystoscope; XI, double catheterizing telescope introduced into sheath.

employed. It would be quite futile to attempt in the space at our disposal to describe in detail the use of these instruments, which must be learned by practice.

CYSTOSCOPES FOR OTHER USES.

Kutner was the first to devise an instrument for taking pictures of the interior of the bladder through a cystoscope. This photographic cystoscope has been further developed by Nitze, Casper, and others. Excellent views are ob-

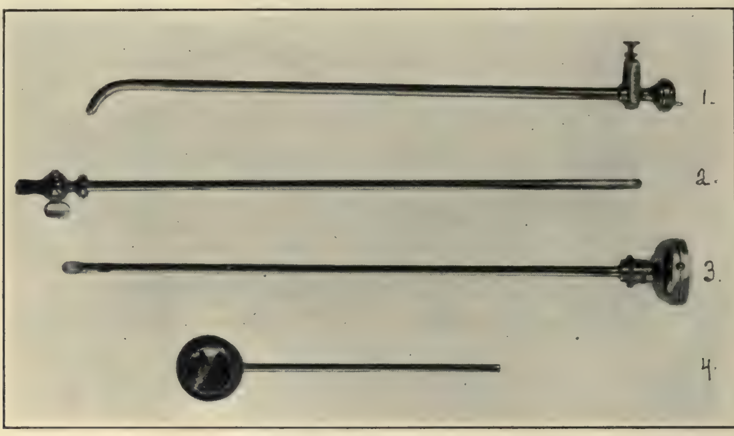


Fig. 153.—Kollman's Cystoscope. This instrument can be sterilized by boiling. 1, the sheath; 2, an irrigating part; 3, the optical carrying part; 4, cap, covering the ocular with handle attached.

tainable, and some color photographs on lumière plates of remarkable beauty have been obtained. Instruments of this type are of value for obtaining records and illustrating findings.

Jacoby (*Centralbl. f. d. Krankh. d. Harn u. Sex.-Org.*, 1905, xvi, 535) describes a stereoptical cystoscope which, while only 21½ Charrière in caliber, contains 2 complete systems of lenses and gives plastic views of the interior of the bladder.

We have thus rapidly gone over the field of the cystoscope as a whole, but we wish to call attention briefly to two or three types of cystoscopes which are of practical value in diagnostic work. These are the Kollman inspection cystoscope, the Brown-Buerger cystoscope, and the Bransford Lewis cystoscope.

Kollman Inspection and Irrigation Cystoscope.—This instrument has proved a very good one for ordinary bladder inspection. It consists, as shown in Figure

153, of a sheath which is essentially a metal catheter and can be used for that purpose, and of an optical part to which the lamp is attached. This fits in the sheath. The ocular lens is closed by a metal cap with a handle, which is of advantage in sterilizing. This instrument can be sterilized in boiling water.

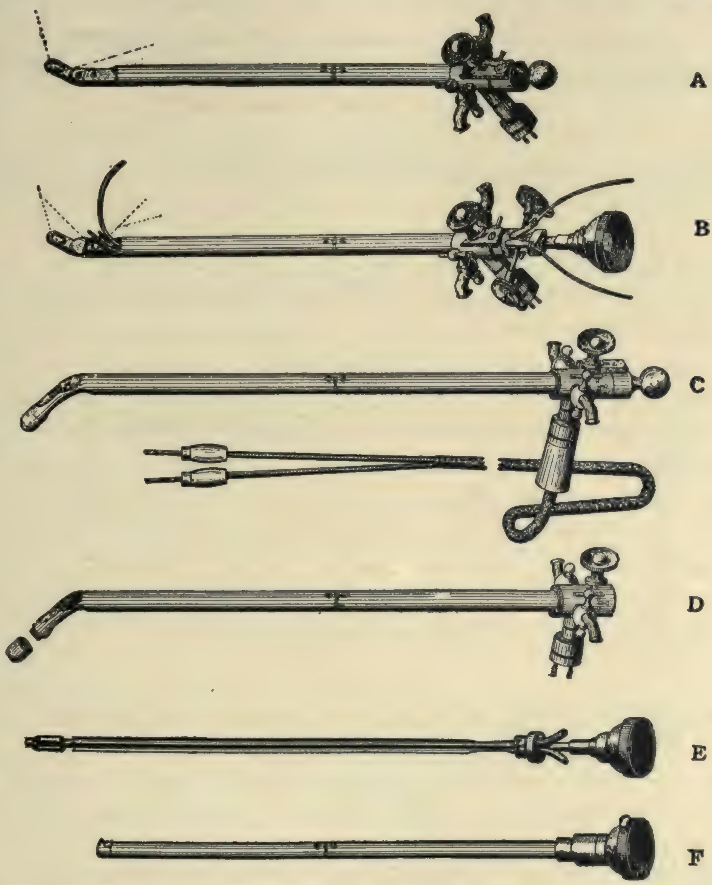


FIG. 154.—BROWN-BUERGER CYSTOSCOPE. Showing sheath, catheterizing and inspecting parts.

Brown-Buerger Cystoscope.—This instrument is a splendid all-round catheterizing and inspection cystoscope (Fig. 154). It consists of a sheath, an obturator, an inspection telescope, and a catheterizing telescope. The sheath is cylindrical, 24 French in diameter, and measures $8\frac{1}{2}$ inches in length. In the end of this sheath is a short lamp which gives the beak to the instrument when

screwed in place. Immediately behind the lamp is a window. Near the ocular end of the sheath are two stopcocks which allow the filling or emptying of the bladder with the lens-carrying parts in place. The obturator is also perforated and permits irrigation when in place. The cystoscope is introduced into the bladder with the obturator in place. This is then withdrawn and replaced by the lenses. The inspection telescope carries the entire lens system of the ordinary Nitze, and when introduced, its prism fits into the window in the sheath. The catheterizing telescope consists of the same optical apparatus, and, in addition, grooves for two catheters, and it is further provided with an Albarran catheter guide. The catheter guide, which is placed immediately behind the lens, is unusually long and strong, and permits the deflection of quite large catheters with comparative ease.

Bransford Lewis Universal Cystoscope.—This cystoscope consists of a sheath carrying the lamp. It is only 23 French in caliber. Into this sheath fit a number of different parts. These parts give: (1) a direct forward view similar to the Brenner cystoscope; (2) a right-angle lateral view, similar to the Nitze; (3) a retrospective view similar to Nitze's retrograde cystoscope; (4) a part for catheterization of the ureters by the direct method of Brenner; (5) a part for the catheterization of the ureters by the Albarran method; (6) an excellent irrigating system. The different parts of this instrument are shown in Figure 155. This instrument affords a splendid all-round apparatus for examination of the bladder and catheterization of the ureters. After introduction of the sheath all the separate parts can be used at one sitting, if necessary. It is applicable to both men and women.

THE SOURCE OF ELECTRICITY FOR LIGHTING THE CYSTOSCOPES.

The market contains a number of simple universal transformers and current regulators which can be screwed into any electric socket where electricity can be obtained; this is the best appliance. Such a transformer is shown in Figure 147.

In the country, or where it is not convenient to use this, an electric battery especially adapted for the light to be used must be employed.

DISINFECTION OF THE CYSTOSCOPE.

The Kollman cystoscope, as already mentioned, can be boiled. The lenses of most cystoscopes will not stand this best of all methods of sterilizing. The

sterilizing problem has been greatly simplified by the introduction of the compound cystoscope. In the old-fashioned Nitze and Casper types it was a very serious problem to thoroughly sterilize the instruments, especially the catheterizing ones. A good method of sterilization is to thoroughly wipe off the in-

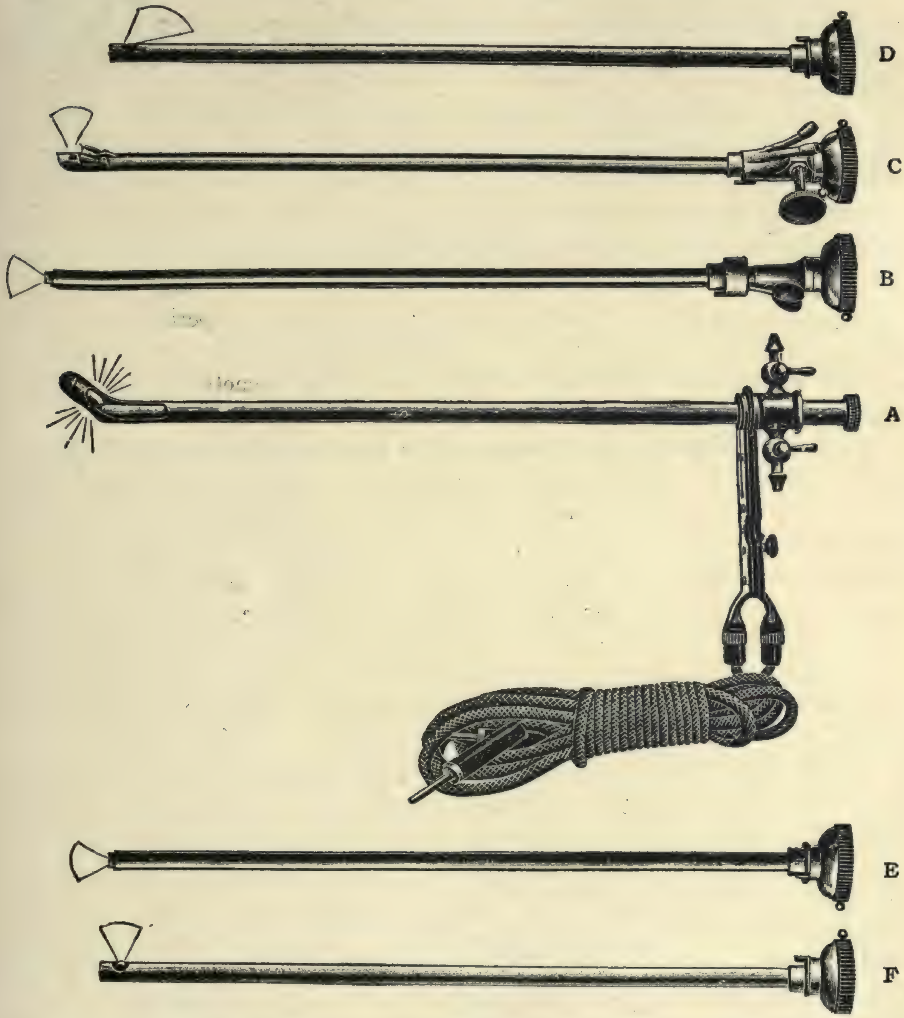


FIG. 155.—BRANSFORD LEWIS UNIVERSAL CYSTOSCOPE. A, sheath, obturator and connecting cord; B, direct catheterizing part; C, indirect catheterizing part; D, retrograde optical; E, direct vision optic; F, indirect vision optic.

struments with tincture of green soap and then to put all parts except the oculars in pure carbolic acid. This should be very carefully and thoroughly carried out. The sterilization in the carbolic should be a prolonged one after using the cystoscope in an infected case.

The sterilization of ureteral catheters can be carried out in the autoclave, a number of them being kept in a sterile towel until ready to use. A 2 per cent. solution of formalin heated to 75° C. thoroughly sterilizes them in two or three minutes.

CYSTOSCOPIC EXAMINATION.

Position of Patient for Cystoscopic Examination.—The chief advantage of the telescope cystoscope over that of the air lies in the easy position which the patient can take. This is especially of value in very fat or very ill people. This posture is a dorsal one with either no elevation of the table or a very slight one. The examining table should be a comfortable one and arranged with a suitable rest to support the legs. The position is the ordinary perineal lithotomy posture.

Preliminary Filling of the Bladder.—It is possible and sometimes of advantage to distend the bladder with air and examine through this. The routine and most useful procedure is to distend it with a transparent fluid. For this purpose, water, salt solution, 2 per cent. boracic acid solution, and occasionally a carbolic acid solution $\frac{1}{8}$ of 1 per cent., should be used. The urine should be emptied from the bladder by means of the catheter, and if it is turbid or bloody the bladder should be washed out, until the fluid returns perfectly clear. The ideal distention of the bladder for examination is 150 c. c. of fluid. It is possible to make an examination with a distention of only 60 c. c. and even less.

Anesthetics.—General anesthesia is practically never necessary. It is of distinct disadvantage in that injury may be done to the bladder through the fact that the patient cannot complain. As a rule no anesthesia is necessary. In sensitive bladders one may use a preliminary hypodermic injection of morphin. Cocain is practically never to be used. Bransford Lewis advises the use of alypin tablets in the case of a sensitive posterior urethra in the male. He puts the dry tablet containing $1\frac{1}{8}$ grains into the urethra and allows it to melt; from 2 to 4 tablets give perfect anesthesia and produce no toxic symptoms.

The Examination.—The actual cystoscopic examination should be carried out in a careful and routine manner. The exact details will vary somewhat with the type of cystoscope used and depend to some extent on whether a male

or female bladder is to be examined. After preparing the patient, the operator should test his instrument to be sure that the light is in order and that the optical system is clear. With the compound instruments almost any form of sterile lubricant employed for ordinary catheterizing can be used. With the older types the best lubricant is boroglycerid, since it does not smear the lenses, which are exposed. The cystoscope is then introduced. The cystoscope is best held in the left hand, and the right hand is used in turning the instrument about to view the different parts of the bladder. This must be done in a careful and systematic way, so that no part will be overlooked. There are several landmarks of great value which help in this. These are the bubble of gas which rises to the top of the bladder, the region of the sphincter, and the ureteral orifices. Immediately on introducing the cystoscope, find the bubble of air, draw the cystoscope back until it touches the sphincter, then turn it around at an angle of 180 degrees and lower the ocular end. This brings the trigonum into view. One can observe the ureteral orifices.

Bearing in mind that each complete turn of the cystoscope shows a complete band around the bladder, and that with each inclination a different level is obtained, one can begin at the sphincter margin and successively cover the entire bladder. With the degree of inclination of the cystoscope the different parts may be conveniently compared to the different hours on the face of a clock.

When the normal bladder is insufficiently lighted the color is a dull red; this is an indication to turn on more light. With sufficient illumination the normal bladder varies in color from a bright yellow to a brownish red. The color is dimmer and darker in parts of the bladder more remote from the prism. When the bladder is unevenly distended transverse folds or rugæ are frequently seen, which may, to the beginner, simulate papillomata and other growths. Under such conditions, a little more fluid should be introduced. Then, beginning with the apex, the posterior wall, the lateral walls, the fundus immediately behind the trigonum, and, finally, the trigonum itself, are observed.

To place the ureteral orifices, find the posterior edge of the vascular trigonum and turn the cystoscope to an angle of 30 degrees, which brings it about to eight o'clock for the right ureteral orifice, and four o'clock for the left. In most cases this will disclose the orifice. Where it does not, careful search must be made, swinging in this arc between four and eight o'clock. In accessory or misplaced ureteral orifices, in the sphincter region, the direct vision telescope is much simpler. In certain cases, where the ureteral orifice is very small, or lies in a fold, it is much more easily found after giving indigo-carmin subcutaneously, as suggested by Voelcker and Joseph.

The trigonal area is slightly different in the male and female, the prostate gland in the male causing a fairly even prominence. In the female there is a prominence due to the cervix, and rather deep recesses on either side. These recesses, on account of the distance of the wall, look dark, but are quickly illuminated when the prism is brought close to their walls.

CATHETERIZATION OF THE URETERS.

The catheterization of the ureters by the direct method can readily be carried out in water distentions with the Bransford Lewis direct catheterizing apparatus. The procedure is so essentially similar to that of the open-air method that no special description seems necessary. With the indirect method we have followed with excellent results the suggestions of Buerger, which are as follows: (1) Find the ureteral orifice; (2) bring the ocular end of the cystoscope slightly to the opposite side of the patient. (3) Elevate the shaft so that the ureteral orifice occupies about the middle of the field; the distance of cystoscope from orifice should be far enough to give the appearance of a normal orifice, as seen through an air cystoscope; this is approximately 3 cm. distant. (4) Slightly elevate the catheter guide and push the catheters in so that they extend from 1 to $1\frac{1}{2}$ cm. beyond the field of vision; continue elevating the guide until the tip reaches a point just above the ureteral orifice. (5) Push the tip of the catheter into the ureteral orifice by raising the cystoscope and pushing it into the bladder. The catheter is then pushed in a little way, when the catheter guide is depressed and the catheter completely introduced. After catheterizing the one ureter, the other may be catheterized at the same sitting. In place of this procedure, when it is sometimes necessary to get closer to the ureter, use less deflection of the catheter, and, in place of introducing it by movement of the cystoscope, introduce it by pushing the catheter inward. With the Brown-Buerger instrument the telescope can be stripped off of the catheters, which are left in place in the ureters. One can, then, by simple manipulation, remove the sheath itself and leave the catheters in place (Fig. 156).

Thus, in outline, we have given the general directions for the use of the water cystoscope. Its actual use is only gained by much practice and study. For the beginner it is of distinct advantage to start by examining female bladders, and those in which there is but little disease. The examinations here are much easier and the normal relationships are more quickly learned. For the many descriptions of the method as used in pathological conditions, the reader is

referred to the special books on Cystoscopy such as Knoor, Casper, Fenwick, and others. After learning the method of using the instruments, each ob-

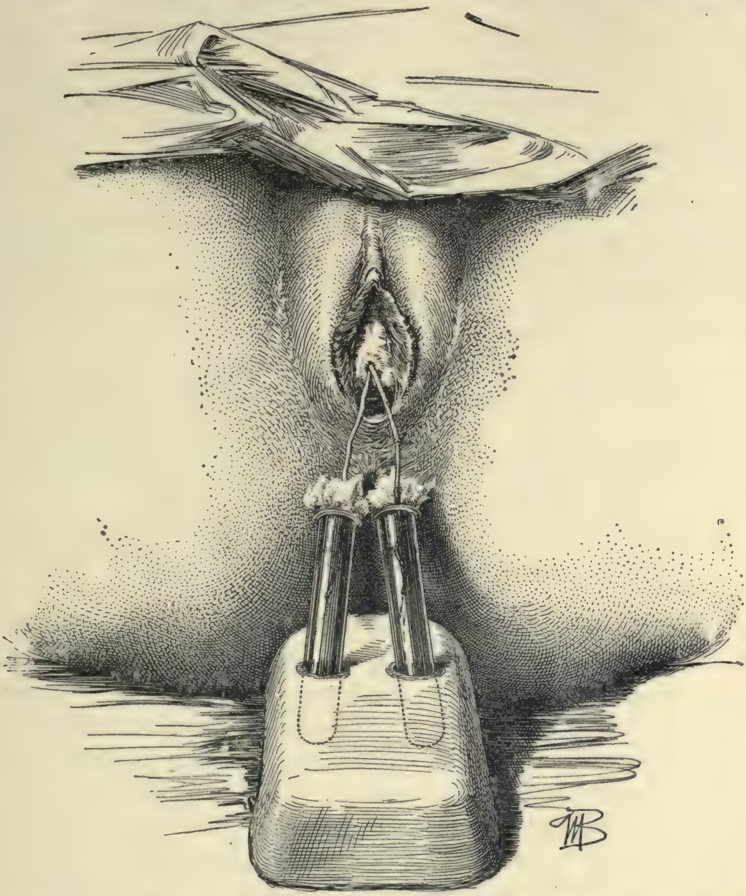


FIG. 156.—POSITION OF PATIENT AND METHOD OF COLLECTING URINE AFTER BOTH URETERS HAVE BEEN CATHETERIZED AND CYSTOSCOPE REMOVED.

server gradually develops his own technique of inspecting the bladder and catheterizing the ureters. We have considered, in the chapter on Open-air Cystoscopy and in other parts of this book, the various uses to which ureteral catheterization can be put, and pointed out many of the pitfalls into which the inexperienced can fall in interpreting the results, and will not refer to them here.

CHAPTER XI.

METHODS OF EXAMINATION OF THE FUNCTIONAL CAPACITY OF THE KIDNEYS.

Recent times have marked rapid advance in methods of estimating the functional capacity of organs both in health and disease. Perhaps in this direction no other organs have received so much attention as the kidneys, it being recognized that the chief danger in disease is not mere alteration in anatomical structure so much as reduction of power to functionate properly. In studying the kidney we have learned that in some cases gross anatomical changes sometimes occur with very little injury to the functional capacity, while in others the reverse condition obtains. Granting that alteration in structure generally goes hand in hand with alteration in function, it must be yet remembered that many exceptions are met with, and it should also be constantly kept in mind that, if the disease is not progressive, it is the capacity to functionate that affords the criteria of the value of the kidneys.

By a wise provision of nature most vital organs have a capacity to functionate far beyond what is demanded of them. This reserve power is particularly well marked in the kidneys. One of two healthy kidneys can be removed without the slightest danger or distress to the individual. By animal experimentation, as well as by observation on patients who have been injured, it is known that not only one kidney but half of the other can be dispensed with without destroying the power to live. It is this fact which explains the apparent health and freedom from all discomfort enjoyed by many individuals with grave bilateral kidney disease, such as being able to go for years without any knowledge of the disease, when some slight attack—a cold or infection—suddenly brings on acute renal insufficiency.

In a preceding chapter it is said that the usual function of the kidney is the removal from the body of various waste products; it also affords the most important regulatory apparatus of the sodium chlorid and water contents of the body. When sufficiently functionating, the kidneys preserve a remarkable uniformity in the constitution of the blood, and it is believed that this uniformity is essential to health and even to life.

We cannot do without kidney tissue, although to some extent other parts of the body vicariously act for it. So far as the water regulation is concerned, the skin, the lungs, and the alimentary canal, with its glands, all help. To a limited extent they participate in the removal of some of the waste products ordinarily taken care of by the kidneys. Such action, however, is feeble, and if both kidneys be removed in a human being death will result in from ten to twenty days.

Before the catheterizing period more than one surgeon had to involuntarily face a horrible experience. He had, perhaps, removed a tubercular kidney to find that it represented the only functionating renal substance in the body, the other being absent congenitally, or already destroyed by the disease. Such calamities are avoidable only by catheterization of the ureters and collection of the separated urines.

THE IDEALS OF THE FUNCTIONAL TEST.

Before taking up the actual methods employed in estimating the capacity of the kidneys, and considering their respective values, it seems advisable to bring clearly to the reader's mind the aim of such tests and what can be hoped from them. The ideal functional test should be one which is easily applicable, which does not impose long and trying experiences on the patient, nor subject the physician to difficult and expensive procedures. This first demand in the way of a test, however, is not the most important one, and could be neglected, provided some one method met the other conditions to a higher degree. The ideal test should show not only whether the kidneys are carrying on the necessary amount of function, but likewise their exact reserve force. It should afford, by means of ureteral catheterization and collection of the separated urines, a means of determining what part of the total function each kidney is capable of bearing. In conditions where a kidney is to be removed, it should inform as to whether the other can easily maintain life.

It is thus apparent that in considering the functional test question we have two separate and distinct problems: one, to determine the efficiency of the kidneys in reference to the body as a whole; the other, to determine the relative efficiency of the two kidneys.

RENAL INSUFFICIENCY.

Several well-known types of renal insufficiency present themselves at once to the reader's mind. In the typical, chronic, parenchymatous nephritis there is the scant urine loaded with casts and albumin, the dropsy, and ascites due

to failure in excreting water and sodium chlorid. The entirely different but equally familiar insufficiency features of chronic interstitial nephritis with its polyuria, low specific gravity, albumin-free and often cast-free urine, with its headaches, nauseas, mental disturbances, high blood pressure, hypertrophied heart, coma, and convulsions, need no functional test to show that the kidneys are no longer doing their proper work. In such cases the physician will tax the patient neither by operation nor by treatment in any way that can be possibly avoided, but, on the other hand, will use every means to make the work of the kidneys less. Before, however, disease has led to these marked insufficiencies, there are the intermediary stages during which none of these symptoms are present, and in which the patient feels well. An ordinary examination of the urine and of the heart may enable the observer to determine that there is a disease and its nature, but does not tell whether there is but slight impairment of the kidneys or whether they are working at their maximum capacity. This stage is properly called the stage of complete compensation. A patient can eat and drink and exercise and live as he pleases; in fact lead a normal life. In a more advanced degree of insufficiency he may still feel well, provided he is careful as to diet, exercise, and exposure, but immediately on any indiscretion in one of these directions he begins to feel and show some signs of insufficiency. It is in this stage of nephritis that the skillful physician can do so much for the comfort of the patient and the prolongation of his life. In a last stage the kidneys have lost so much capacity that, even when every tax consistent with the maintenance of the general health is taken off, they still fail to eliminate the waste products and allow them to accumulate in the body; then, death is close at hand.

The loss of function may be permanent or temporary. In the chronic degenerative changes referred to, it is usually permanent. On the other hand, in acute nephritis and in many surgical conditions there may be a very great loss of function temporarily, which is regained with the removal of disease. It should be kept in mind, therefore, that the function at any given moment in diseased kidneys may not represent what they can do under ordinary circumstances. It seems quite likely that individuals in health present great variations in their kidney capacity, just as hearts vary and muscles vary. As we shall show later, there is a marked variation in certain functions in normal individuals. It is possible, too, that there are wide variations in the demands on the kidney by different body economies. In a general way, the larger the individual and the more the food intake necessary to live, the greater is the demand. It seems quite likely that there are other features, however, far more important than this. Some bodies are able to get a great deal more energy

out of a given amount of food than others. Such people normally throw less tax upon the kidneys and can do with less renal tissue.

THE POSSIBILITIES OF THE FUNCTIONAL TEST FROM THE PHYSIOLOGIST'S STANDPOINT.

In a previous chapter was presented a review of the facts and theories in regard to the physiology of the kidney. The extreme complexity of this function is at once realized. We see how the different parts of the tubular system possess entirely different functions, how the function depends upon the blood pressure, the amount of blood flowing through the kidneys, the physical and chemical constitution of the blood. How greatly do these features depend upon the perfect working of other parts of the body, especially the heart and the nervous system! If we could tell in each individual how much blood flows through the kidney, and at what pressure in a unit of time; how much the separate parts of the tubular system receive of this blood; and, furthermore, be able to determine the physical and chemical properties of the blood in the same way that we are able to determine the physical and chemical properties of the urine, there seems to be little doubt that there would be clinical methods which would give us very exact figures of the functional capacity of the kidneys. Unhappily we have no such means and probably never will have them. At the present time we can only investigate along two of these lines, the constitution of the blood and the constitution of the urine. Our methods for determining the nature of the blood, as we shall show, are most imperfect. If we assume that in renal insufficiency there is an accumulation of waste products in the body, there should be in all probability an accumulation of the same in the blood, but this does not of necessity follow, as there are other mechanisms in the body than the kidneys for keeping the equilibrium of the blood. The ascites and anasarca of Bright's disease afford an illustration. The tissues themselves take up and hold products out of the blood which normally would be eliminated by the kidneys. The gross amount of substances in the urine depends largely in health upon the intake of foods and upon the metabolic processes of the body. We know that in certain diseases there is a great deal more waste than is actually represented by the food accumulated. This is at the expense of the tissues, and such patients are losing weight and strength. Take an individual constituent of the urine, such as urea, the amount of it which appears in the urine, in one hour or twenty-four hours, should vary with the amount of the substance in the blood and body. In the last stages of renal insufficiency it is possible for a rather large amount of urea to be excreted in

the urine in 24 hours, and yet for a steady accumulation to be going on in the body. This simply means that, with high pressure on the inside, an amount can be squeezed through the kidney which could come through a normal kidney under much less tension. Now, to carry on this line of thought, it is at once evident that not even a knowledge of the constitution of the blood, the constitution of the urine, and the amount of blood flowing through the kidney with its pressure, can enable us to form an absolutely correct idea, whether both kidneys are carrying on or are capable of carrying on their function in the body economy.

While all the facts relating to the efficiency of the kidneys as a whole are difficult to obtain, the comparison of the two kidneys, on the other hand, is relatively simple. As a general principle, it is fairly safe to assume that the blood flow and pressure on the two sides are equal, and that the character of the blood is the same, so that the only feature to be determined in regard to the efficiency of the kidneys is a comparison of the constituents of the urine from the two sides.

In detailing different tests there will be given the normal relations of excretion between the kidneys, but here we will confine ourselves to the statement that under perfectly normal conditions the two kidneys excrete urine the same in amount and in character. This feature of normal kidneys was first definitely proclaimed by Casper and Richter. As shown later by Albarran and now generally recognized, this statement must be modified; in short intervals of time, 10 or 15 minutes, there may be wide variations between the two kidneys, variations growing much smaller when the unit of time is one hour, and still smaller when 2 or more hours. In 24 hours the variation between the two sides, with both kidneys normal, is very small. The methods employed for estimating the relative function of the two kidneys are methods dependent upon examination of the urine associated with determination of the total function. Methods of determining the functional capacity of the kidney which rest on blood examinations are not of value for this purpose.

METHODS WHICH DEPEND ON EXAMINATION OF THE BLOOD.

Our knowledge of the constitution of normal blood is so defective, and the technical methods of examining it so imperfect that, as yet, no very practical method has been evolved. The first thought occurring to a student of renal function is that, not what is excreted through the kidneys, but what remains in the system and particularly in the blood, indicates whether or not the kidneys are functioning as they should.

The best known of these methods is blood cryoscopy, originally introduced by Koranyi. It has found its chief user in Prof. Kümmel of Hamburg. The test is based upon the assumption that insufficient functioning of the kidneys is inevitably followed by increasing concentration of the blood plasma.

The freezing point of normal blood is fairly constant, being — 0.56° C.

The technique of the test is essentially the same as that for determining the freezing point of urine (p. 310). At least 10 c. c. of blood must be obtained, which is usually done by aspiration from a vein. Either whole blood or defibrinated plasma may be used.

Kümmel (*Berliner klin. Wchnschr.,* 1906, xliii, 901; 982) states that if the reduction of the freezing point is lower than — 0.60° C. a degree of insufficiency exists which contraindicates the removal of one of the kidneys. He cites several instances of death where he has operated against this indication. On the other hand, with a freezing point higher than — 0.60° C., he has never had a fatality.

We are not personally prepared to pass on this question from experience. We have used cryoscopy in too limited a number of cases. Other observers have shown that marked reductions of the freezing point may occur independent of any renal insufficiency in diabetes mellitus, in incompensated heart lesions, in typhoid fever, in patients suffering with abdominal tumors, and other conditions. On the other hand, in the anemias and cachexias a lowering of the freezing point to not more than — 0.50° C. is common.

Roeder and Sommerfeld (*Berliner klin. Wchnschr.,* 1902, xxxix, 519; 544) have shown that the freezing point of blood is lower when the patient is on a mixed diet than when on pure proteid food.

Israel, Rovsing, and others have reported successful nephrectomies where the freezing point has been much lower than — 0.60° C. Some of these cases have been explained as infected kidney on one side and toxic nephritis on the other. In the anurias due to stone, and even where there is no anuria during an attack of renal colic, one often meets with very low freezing points.

One of the strongest facts against the arbitrary setting up of a definite figure as an indication of renal insufficiency is that in many cases of uremia there is no lowering of the freezing point below the normal figure of — 0.56° C. This may be due either to hydremia or, possibly, as suggested by some, to the fact that the uremic toxin is albuminous and, therefore, not active in lowering freezing points.

Kövesi and Surányi (*Cntrlbl. f. Harn u. Sex-org.,* 1901, xii, 531) use a slightly different method, i. e., they obtained the freezing point, the specific gravity, and the sodium chlorid contents of the blood. They state that in

health the quotient obtained by dividing the freezing point by the specific gravity varies from 50° to 55° C., while in uremias this quotient increases markedly, in some cases going as high as 75°. On the other hand, the quotient obtained by dividing the fixed point by the percentage of sodium chlorid in health varies from 92° to 96°. In renal insufficiency the quotient decreases, and in one case of uremia they noted that it was as low as 48°.

Other investigators have attempted to establish tables by a comparison of the freezing points in the urine and in the blood. These methods are subject to great error and have never been extensively used.

Wright and Ross (*Lancet,* 1905, ii, 1164), McCay (*Lancet,* 1907, i, 1483), and Howard (*University of Penn. Med. Bull.,* 1908, xxi, 67) have devised and used an interesting method of comparing the hemolytic activity of the blood serum with that of sodium chlorid solutions, likewise the hemolytic power of the urine with that of sodium chlorid solutions, and the relative capacity of the blood serum and the urine.

The quotient obtained by dividing the urine dilution by the serum dilution in normal cases is 2 or more. In cases of renal insufficiency it may be much less, even below 1. From what we know of the excretion of substances in the urine and their concentration in the blood, this method would seem of little value so far as an accumulation of salts is concerned. It is also certain that there are substances in the blood which are not salts but yet favor hemolysis, and there are others which prevent it. The technique of the method can be found in the articles referred to, and its value can only be determined by exhaustive tests. The greatest value should rest in the serum test alone. We cannot believe that there is any value in the comparative one.

Winternitz, of the Johns Hopkins Hospital, has made extensive studies of the blood in health and in conditions of renal insufficiency, in reference to its capacity to catalyze hydrogen peroxid. He showed experimentally in animals that with increasing insufficiency the power of catalysis steadily diminished. Catalysis is the property possessed by tissues to cause hydrogen peroxid to disintegrate into water and oxygen. Attempts were made to standardize the reaction so as to make it of clinical use, but while the normal blood is remarkably constant in this capacity it was found that the slighter degrees of insufficiency, which are of importance in diagnosis, could not be determined.

Summing up, it is safe to say that the methods at present in use for determining renal function by blood examination are not sufficiently developed to be of much practical value, and are, of course, of no value whatever in showing the relative function of the two kidneys.

We now pass on to methods which depend upon examinations of excretory products of the kidneys, in other words of the urine.

METHODS WHICH DEPEND ON EXAMINATION OF THE URINE.

As already stated in the preceding chapter, the urine is a most variable substance so far as the quantitative relationship of its various constituents is concerned. It also often contains unusual elements when these are taken into the body. Under normal food and healthy conditions, however, there are certain elements, such as water, urea, and the other nitrogenous bodies, sodium chlorid, and calcium and phosphate salts, which are normal and constantly present bodies. Studies of the urine as a whole made to estimate the total capacity fall into several distinct and separate groups: (1) Methods which take no account of the intake of substances in the body, simply basing on the amount of urine, and particularly of the urine constituents excreted in definite units of time. The shortest unit of time accepted as at all accurate is 24 hours. (2) Methods in which there is careful estimation of the intake of substances in the body and equally careful examination of their output. Examinations of this kind may be conducted with ordinary foods, or with normal substances occurring in urine given in normal amounts or given in large amounts, or with foreign substances, as phloridzin, methylene blue, indigo-carmin, phenolsulphonephthalein, all of which may be given. A third interesting group is that which is represented by Bouchard's test, which consists in an effort to show that in renal insufficiency there is a diminution in the excretion of toxins out of the body.

Certain elements in the urine, such as casts, pus, blood, bacteria, albumin, and sugar, may indicate local disease of the kidney or general disease, but do not give any indication as to the efficiency of the organ. The urine may be entirely free from all these substances, and yet the kidneys totally inadequate; on the other hand, they may be present and with very little interference with the activity. They are simply indicators of disease.

During health and disease the amount of urine, its color, its acidity, its specific gravity, are all largely dependent on the intake of substances into the body. This is particularly true of water. In a healthy individual the amount of urine in 24 hours may vary, depending on the water taken, all the way from 600 c. c. to 28,000 c. c. In certain forms of glomerular nephritis the capacity to take care of the water is greatly diminished. It is evident that the balance between water intake and water excretion can be used as a means of determin-

ing whether the glomeruli are acting properly. It is quite possible for persons with marked renal insufficiency, if they are ingesting large quantities of nitrogen foods, to excrete larger quantities than a healthy individual on a normal diet. There seems but little doubt, however, that the healthy kidneys will excrete more nitrogen than diseased kidneys, if both are taxed highly by the amount of food taken in.

CHEMICAL FINDINGS.

The Urea and Nitrogen Bodies.—In diseases of disturbed metabolism, such as eclampsia, and in starvation, it would be fairer to examine the output of the entire nitrogen bodies. This is especially of interest in that the Kehldorf method is a very accurate one. Rather incomplete studies are at hand to show the relation of the different nitrogen bodies found in the urine in diseases of the kidney. Our personal observations, which are quite limited, seem to show that the proportion of urea to ammonia, creatinin, and the other substances is not materially different from that which occurs in health. According to Julius Mannaberg ("Handbuch der Urologie," Frisch and Zuckerkandl, 1904-5, ii, 472), in the conditions of uremia the urea and the uric acid are proportionally diminished, while the ammonia and the xanthin bases are increased. According to Robin (*Bull. Soc. méd. des hôp. de Paris,* 1903, xx, 836), the normal relation between urea and the total nitrogen is as 80 to 100; in conditions of renal insufficiency this falls to as low as 70 to 100. It would seem, however, that the simplicity of the examination and the fact that urea constitutes the bulk of the nitrogen would always make the urea test the routine one. The urea must be examined for in the twenty-four-hour specimen, and the patient should be on a fixed diet and under known and the same conditions. Examinations over a number of days are necessary in reaching the conclusion. Rosemann (*Arch. f. d. Ges. Physiol.,* 1899, lxxviii, 405) has shown that in perfectly normal individuals there may be nitrogen retention, extending over a number of days, to be followed by periods of excessive excretions. Noorden and Ritter have shown that these conditions are even more marked in cases of nephritis. The amount of urea put out under normal conditions of diet and exercise varies greatly. In general, personal observations show much smaller amounts than commonly stated in the text books. We have frequently seen that on an ordinary diet and with apparently no disease of the kidneys, the excretion may be no greater than 10 grams per diem. H. Labbé (*Presse. méd.,* 1908, xvi, 361) finds that in normal individuals on a standard diet from 93 to 95 per cent. of the nitrogen taken in by the food is excreted in the urine.

The conditions of nephritis are characterized by a smaller excretion. There seems no question that in conditions of renal insufficiency there is a marked retention of urea. As Albarran points out, this is shown in comparing the work of the two kidneys, which of necessity are under the same conditions so far as the blood is concerned. We personally believe that a comparison of the ureas or the total nitrogen from the two sides gives valuable data in regard to the relative efficiency of the two kidneys. On the other hand, it is quite impossible to draw conclusions as to the total renal function by this method without very long and trying studies extending over days, which renders the method of little clinical value.

Sodium Chlorid.—In the cases which come to the surgeon chlorid estimations are of but little value in determining the capacity of the kidneys to functionate. The amount of this salt excreted will depend on the amount ingested. It shows a tendency to be excreted in surgical diseases of the kidney much better than the nitrogen substances. This is clearly shown in one-sided kidney disease, and has been especially emphasized by Albarran ("Exploration des fonctions rénales," Paris, 1905). On the other hand, in parenchymatous nephritis there are frequently marked retentions, and these retentions are capable of producing edema. Every physician is familiar with the danger associated with giving salt solution hypodermically to nephritic cases. Grünwald (*Arch. f. exper. Pathol. u. Pharmakol.,* 1909, lx, 249) has shown in rabbits that, by giving diuretin, he can so increase the excretion of sodium chlorid that the animal shows symptoms of poisoning which are only relievable by giving it additional chlorid. According to Timofiew, the edema of chronic parenchymatous nephritis is due to the entrance into the blood of lymphagogue substances derived from the diseased kidneys. Without these substances the sodium chlorid will not cause the condition. In chronic interstitial nephritis the elimination of the chlorids, according to F. de Grazia (*Riforma medica,* 1903, xix, 729), are quite normal.

Several of the methods of cryoscopy of the urine are combined with sodium chlorid estimations. The reduction in the freezing point due to the sodium chlorid can be thus determined and deducted from the total reduction, and in this way the reduction due to other substances than sodium chlorid determined. The methods of Koranyi, Claude, and Balthazard depend on this kind of estimation.

The Phosphates.—There are no very extensive studies in existence in regard to the elimination of phosphates by the kidneys in health and disease from the standpoint of the functional test. The average daily excretion is about 3.25 gr. This can vary greatly, depending on the character of the food and

the rapidity of metabolism. As stated in the Physiology chapter, the phosphates normally excreted are secreted through the cells of the convoluted tubules. The phosphates are present in the blood in some albuminous combinations. Albarran has noted marked variations between the two sides in one-sided disease. He states, however, that in a general way the excretions run parallel to urea. He makes no mention of the effect of polyuria on the output of phosphates. Polyuria does not tend to increase the output in a given interval of time; this puts the phosphates in the class of dyes rather than the sodium chlorid and urea.

CRYOSCOPY OF THE URINE.

By means of the well known physico-chemical procedure of determining the freezing point, it is possible to determine the molecular concentration of the urine. The Greek symbol Δ has by universal convention become the sign for the freezing point of solutions; for example, the Δ of distilled water is 0° C. When any salt goes into solution it tends to depress the freezing point in proportion to the concentration of the solution. The lowering of the freezing point of distilled water by a 1 per cent. solution of any salt is termed the specific depression of the freezing point for that salt. The molecular weight of the substance is not a factor in determining the reduction, which corresponds to the number of molecules in solution. Substances which are electrolytes depress according to the number of ions in solution. As a result the depression due to sodium chlorid, which is an electrolyte, is much greater in proportion than for urea, which is not a conducting substance.

Method of Determining the Freezing Point.—The apparatus for determining the freezing point consists of a very delicate Beckmann thermometer graduated to one-hundredth of a degree. This thermometer is held by a stopper in the tube in which the substance to be frozen is placed. Through a separate opening in the stopper is a little wire stirrer. The tube containing the thermometer fits into a larger one which contains air. This larger tube is then placed in a large cylindrical glass vessel which contains the freezing mixture, usually ice and salt water. There is a thick wire stirrer for the freezing mixture and a coarser thermometer for determining the temperature of the water and ice.

The temperature of the freezing mixture should not be lower than 5 degrees below that of the substance to be frozen. At least 10 c. c. of urine should be taken. It is necessary to frequently restandardize the Beckmann thermometer. The stirring should be continued and regular. As the urine cools the

mercury descends in the thermometer; just as ice begins to form it begins to rise rapidly and ascends to a point which is the true freezing point. When a large number of specimens are to be examined in succession it is advisable to cool before submitting them to the test. In order to be at all efficacious in determining the total renal capacity, specimens of the 24-hour urine must be taken. It is quite difficult to prevent precipitates of the salts which will alter the result. This sometimes occurs during the freezing. From what we have already said, it is evident that the freezing point reduction depends on the dilution of the urine, and in normal cases the dilution is dependent on the amount of fluid which the patient drinks. The original conception of Koranyi, who introduced the method, was that the difference between the freezing point reduction of the sodium chlorid and the total salts of the urine represented the activity of the secretory cells in the convoluted tubules. This is not borne out by established facts of the physiology of the kidney. The freezing point of normal 24-hour urine varies all the way from $-0.8°$ to $-2.3°$ C. In cases of chronic interstitial nephritis, as pointed out later, the freezing point corresponding to the specific gravity is, even on limited fluid, not greatly reduced.

By restricting the fluid intake Koranyi thinks that the formula obtained by dividing Δ by the sodium chlorid output is of value. The sodium chlorid percentage is the figure taken, and the results in normal cases vary from 1.7 to 2. Claude and Balthazard take into account not only the freezing point reduction but the amount of urine. They arbitrarily assume the number of molecules in solution is equal to Δ V (the V being the amount of urine in cubic centimeters). They divide this result by the weight of the individual, and thus secure the activity per gram of animal. This represents the total molecular concentration given by each unit of weight. They estimate the freezing point reduction due to the chlorids, and represent it by the letter δ Then the $\frac{\Delta}{\delta}$ shows the relations of glomerular and tubular activity. This is normally from 1.49 to 1.69.

As a means of determining the total renal efficiency we do not regard the cryoscopy of the urine as a whole of much value. It is difficult to conceive that the formula of Koranyi and Claude and Balthazard furnishes as good evidence as that obtained by chemical analyses. For chemical analyses to be of any accuracy whatever, the examinations must be carried on for days and the patient must be on fixed quantities of food, both liquid and solid. The amount of food and drink consumed by him must also be accurately known. When these conditions are fulfilled, chemical analysis appears to be a more reliable means of determining renal efficiency than cryoscopy.

FUNCTIONAL TESTS WHICH DEPEND ON GIVING SUBSTANCES FOREIGN TO THE BODY BY THE MOUTH OR HYPODERMICALLY AND STUDYING THE METHOD OF THEIR EXCRETION IN THE URINE.

A number of substances have been employed in this way; some of them have been very extensively used and remarkable claims made for their efficiency. To these tests belong the phloridzin, the methylene blue, the rosanilin, the phenolsulphonephthalein, the indigo-carmin, the potassium iodid, the salicylate of sodium procedures. In addition may be added the polyuria test with water, the sodium chlorid test, and the urea test. It would be quite impossible to review all these tests and give findings worked out in each case. We content ourselves with referring the reader to the immense literature of the subject, and limit critical discussion to those methods which have proven of most value to us. The procedures which have been tried most extensively are those of phloridzin, methylene blue, indigo-carmin, and experimental polyuria by means of water. The tests with which we personally have had considerable experience are the indigo-carmin, the phenolsulphonephthalein, and the experimental polyuria.

Phloridzin Test.—Phloridzin is chemically classified as a glucosid, originally discovered by Stas and Konick in 1855. Its capacity to produce glycosuria was noted by von Mering in 1885. Klemperer in 1896 (*Verhandl. des Vereins. f. innere Medicin zu Berl.,* 1896, xvi, 174) and Magnus-Levy (*Verhandl. f. innere Med. zu Berl.,* 1896, xvi, 485) employed the substance subcutaneously in cases of nephritis. The former, using small doses, found that in nephritis no sugar appeared in the urine; the latter, after using large doses, that it practically always occurred. The first attempt to study the drug and its effect in a thorough way was made by Achard and Delamare (*Bull. et mém. Soc. méd. des hôp. de Paris,* 1899, xvi, 379). Since these original contributions there has been an immense literature developed on the use of this substance. In the surgical world Casper of Berlin has been its great defender. Since his original communication (Casper and Richter, "*Functionelle Nierendiagnostik,* etc.," Berlin, 1901) he has used it in hundreds of cases and made many communications in regard to it.

Just how phloridzin acts is not known. It appears, however, to give the cells of the convoluted tubules the capacity to remove grape-sugar from the blood and likewise to inhibit the resorption power of the tubule for water and sodium chlorid in a manner similar to that of caffein. That the glycosuria is the true renal diabetes is evidenced by the experiments of Minkowski, Zuntz, Pavy, Brodie, and Porcher. As evidence that the sugar due to phloridzin does

not come through the glomerulus like water and sodium chlorid can be offered the experiments of Marcusen, who tied off the artery to the glomeruli in the frog's kidney and found the sugar still secreting. Furthermore, the well known fact that the amount of sugar excreted after a given dose is not at all influenced by the amount of urine put out is an observation which has been made by every observer, and which we ourselves have confirmed.

The solution of phloridzin usually employed is a one-half per cent., 1 c. c., representing 5 mg. of the substance. The solution must be warmed to secure perfect results, as the phloridzin tends to precipitate out in crystals. The dose employed by Caspar and Richter is 1 c. c. Albarran ("Exploration des fonctions rénales," 1905, Paris) advises 4 c. c. The substance is not at all toxic and can be used as high as 2 gm. doses.

The larger the dose the greater the excretion of sugar, and the longer its duration. With a small dose there may be no sugar excreted; with a large dose, in a diseased kidney, considerable. After giving a 1 c. c. dose the sugar begins to appear in from 15 minutes to half an hour, and continues for from 2 to 4 hours. The actual amount of sugar excreted varies from $\frac{1}{2}$ gr. to $2\frac{1}{2}$ gr. Kapsammer (*Wiener klin. Wchnschr.,* 1906, xix, 904) gives great importance to the time of the appearance of the sugar in the urine, and states that after giving 2 c. c. of the solution hypodermically, the sugar mixes with the urine in from 10 to 15 minutes. If it does not appear within 30 minutes the indication is that there is severe disease of the kidneys. If it does not appear in 45 minutes it would be hazardous to do a nephrectomy. Kapsammer's view is refuted in many investigations. Salomon (*Berl. klin. Wchnschr.,* 1909, xlvi, 2299), in a very careful study, found that in from 3 to 5 per cent. of apparently normal individuals there was no secretion of sugar whatever, and that in more than 30 per cent. of the cases it appeared later than 15 minutes. This entire absence of sugar noted by Salomon has been noted by Albarran in many cases of slight one-sided disease. Our own experience is limited, but we have had one apparently normal individual in whom the dose of 2 c. c. gave no sugar. Casper, who places the greatest reliance on this test, states that, while it cannot give evidence as to the functional capacity of both kidneys so far as the quality of the parenchyma is concerned, nevertheless it does give accurately the amount of functioning parenchyma present in each kidney. We show later that the two kidneys normally secrete equally and that the character of the glycosuria is equal, or nearly so, on the two sides. Casper says that under like conditions, particularly the avoidance of fluid, the two healthy kidneys will secrete sugar equally in a short interval of time, the sugar diminishing in proportion to their injury. He is very careful to prevent polyuria during his

examination. The estimation he makes is solely the percentage of sugar obtained in a given interval of time. Albarran, in a series of careful studies, has demonstrated that with every care it is impossible in all cases to compare the percentages of sugar because of the tendency of phloridzin to cause a polyuria. This polyuria is frequently one-sided, if only one ureter is catheterized. Albarran, in periods as long as two hours, has found that the difference of sugar excretions on the percentage basis may vary 20 per cent.; the absolute amounts 15 per cent. The amount of sugar secreted does not give the amount of parenchyma present. Albarran believes that the time and the amount of secretion are of greater importance than the percentage. Salomon has shown that total abstinence from food and water for 13 hours often leads to a complete absence of the sugar, after giving phloridzin. It is often absent after antipyrin or sodium salicylate, and, as Kapsammer points out, is likely to fail if the indigo-carmin test be used at the same time.

Summing up, it seems that the phloridzin test is of very little value in determining the question of total renal capacity. Since the amounts of sugar secreted vary so much in perfectly normal cases, and it may be entirely absent, it in no sense can measure, as Caspar thinks, the amount of renal parenchyma. It is of value in pointing out differences between the two kidneys and occasionally shows a glaring difference which might be overlooked by other methods.

Methylene Blue Test.—This, the oldest of the dye tests to which indigo-carmin, rosanilin, and phenolsulphonephthalein belong, was first employed by Kutner (*Dtsch. med. Wchnschr.,* 1902, xxviii, 140). It has been principally employed by French observers. The reader is referred to the monograph of Achard and Castaigne ("L'exam. clinique des fonctions rénales par l'élimination provoquée," Paris, 1900) and Albarran ("Exploration des fonctions rénales," Paris, 1905).

The method of Achard and Castaigne which is usually employed consists in the subcutaneous injection of 50 mg. of the substance. It begins to appear in the urine in half an hour and reaches its maximum in 4 hours, continuing to be excreted for two days. In addition to the great length of time which this substance takes in being excreted it has numerous other disadvantages; it is excreted in the bile and in the saliva, is partly destroyed in the body, and is partly excreted as a colorless product in the urine. If combined with phloridzin the leuko-product is the only part excreted in many cases. The solution that Albarran employs is a 5 per cent. aqueous one. The chromogen can be made to become blue again by boiling the urine, to which a little acetic acid has been added. The amount of blue can be estimated by the colorimetric method which we use for indigo-carmin and phenolsulphonephthalein. The

points observed are the time of onset of the color in the urine, the intensity of the coloration, the curve of elimination, and the duration.

The dye is well excreted in chronic parenchymatous nephritis, quite poorly in chronic interstitial. There are great variations in the time of excretion and the amount of excretion in normal kidneys. The amount excreted by diseased kidney is steadily less than by healthy kidney, when both are catheterized. It is not influenced by polyuria. The irregular rate of excretion in cases of chronic interstitial nephritis and in cases of hypertrophied kidneys is marked. Taken as a whole, the method is far inferior to the other dyes because the great length of excretion prevents quantitative estimation of the two sides in comparison and prolongs the examination.

Rosanilin Method.—This method was introduced by Lépine (*Lyon méd.,* 1898, lxxxvii, 251; 573). It consists in the use of rosanilin trisulphonate of soda in 1 per cent. aqueous solution. Lépine recommends a hypodermic injection of 1 c. c. of this solution. The color begins to appear in the urine in from 15 minutes to half an hour, reaches its maximum in 3 hours, and is entirely excreted in 12 hours. The amount excreted, according to Dreyfuss (*Thèse de Lyon,* 1898), varies normally from 80 to 97 per cent. The sole factor to be taken account of is the amount of excretion. In interstitial nephritis the amount excreted often falls to from 30 to 40 per cent. In parenchymatous nephritis the amount varies from 27 to 50 per cent. In interstitial nephritis the time of onset is delayed and the time of excretion may extend to 48 hours. In parenchymatous nephritis the onset is often as soon as in the normal, and it may cease being excreted just as quickly as in a normal. Lépine, in comparing the rosanilin excretion with the methylene blue, concludes that the kidney has a different coefficient for excretion for each substance. This method has not been extensively used, and has particularly not been much used by those studying surgical conditions of the kidney and comparing the two sides.

Indigo-Carmin Method.—This method was introduced by Voelcker and Joseph (*Dtsch. med. Wchnschr.,* 1904, xxx, 536). It is considered at length by Voelcker (*Diagnose der chirurgischen Nierenerkrankungen unter Verwertung der Chromocystoskopie,* Wiesbaden, 1906).

The method employed originally by Voelcker and Joseph was largely concerned with the comparative study of the two kidneys and without separate catheterization of the ureters. The indigo-carmin when normally excreted gives an intense blue color to the urine. By means of the cystoscope the two ureteral orifices can be watched and the time noted of the appearance of the blue and, in a general way, of its concentration. The method has received the name of chromocystoscopy. It is of great value in detecting ureteral orifices

and thus securing the catheterization of the side. One can readily study the rate and character of the ureteral ejections. It is certainly possible in many cases, as the authors point out, to obtain most valuable data. The method, however, as a functional test method cannot replace the catheterization of the ureters. In many cases Voelcker has combined the giving of the indigo-carmin with the catheterizing. He notes not only the onset of excretion but the amount and the duration.

Fig. 157.—Apparatus to Determine Amount of Indigo-carmin in the Urine. Apparatus consists of two beakers of 1,000 c. c. capacity each, a burette graduated in hundredths of a c. c., and a pipette graduated in hundredths of a c. c.

We have followed the technique of Voelcker so far as the dosage of the drug is concerned, but in attempting comparisons between the two kidneys, we always catheterize the ureters. It is certain, as we show later, that kidneys still doing good work secrete but little indigo-carmin so far as the percentage basis is concerned.

The drug is non-toxic; very large doses can be given without the slightest evidence of poisoning.

Technique.—We employ the indigo-carmin of Merck, which is a sodium salt of indigo tetrasulphonic acid. It is dissolvable in warm distilled water up to 4 per cent. As the water cools considerable amounts are precipitated. Instead of adding sodium chlorid as Voelcker does, we have found it better to add novocain in the proportion of $\frac{1}{8}$ of 1 per cent. The solution can be sterilized either in the autoclave or by boiling. When used it should always be warmed. The standard dose is 20 c. c., equaling 80 mg. of the drug. This should be injected deep into the gluteal muscles. A specially graduated and perfectly working

syringe should be employed. The injection with the novocain added can be made perfectly painless, and while it is possible to inject as Voelcker does, we have observed that it causes the patient great discomfort.

A simple method of estimating the amount of indigo-carmin in the urine, and one equally applicable to the phenolsulphonephthalein, methylene blue, or any other dye, has given great satisfaction. The necessary apparatus consists of a burette graduated to tenths of a c. c., a pipette graduated in the same way, of 2 glass cylinders of equal height and graduated to 1,000 c. c. (see Fig. 157). In a flask is kept a solution of indigo-carmin used in the proportion of 4 c. c. to the thousand of water. This is used as a standard solution and is poured into the burette. In the pipette one draws up 1/10th of the amount of urine secreted, for example, in the first hour. This is then put in one of the glass cylinders which is then filled with sterile water up to 1,000 c. c. The other cylinder is filled to an appropriate degree with water and then the standard solution run into it from the burette. The reading is made looking through the column of fluid. One carefully titrates from the burette until the color of the two solutions is equal. When they are equal the amount of the solution from the burette is read off and multiplied by ten. This gives the number of c. c. of the standard solution necessary to produce the color in the urine. If the amount is 500 c. c. then the amount of indigo excreted must be 2 c. c. of the original infection, for in a thousand c. c. of the standard there are 4 c. c. of the original. If 20 c. c. have been given the percentage of excretion is 10 per cent. With a little practice this reading can be made very rapidly and is accurate to within a fraction of 1 per cent. Occasionally in very concentrated urines or in very large excretions it is convenient to make greater dilutions than that given by one-tenth of the amount of urine excreted. Whatever the dilution the same principles are to be followed. When the dye is present in concentrated solution the color is an intense blue, and there is very little difficulty in the reading. When the dye is present in small quantities and the color of the urine intense from urobilin, the indigo-carmin takes on a greenish tinge. In order to get this same tint it is only necessary to drop a small quantity of highly colored urine into the cylinder into which the standardizing solution is being run.

When the amount of blue is small, as in the third or fourth hours, it may be necessary to take half or all the urine excreted in order to make the estimation.

Experimental Facts.—Voelcker has shown that when given in very large doses the indigo is secreted both by the kidneys and the liver. In order to cause the liver to secrete, amounts greater than 200 mg. must be given in the

adult man. With a dose of 80 mg. there is no excretion in the bile, as h been observed in cases with biliary fistulæ. In animals in which both kidney have been removed small doses cause the bile to become intensely blue. Accor ing to Dresser, indigo-carmin can be transformed in the body into leuk products. These apparently do not occur in the urine under normal cond tions. Indigo-carmin, when given by the mouth, is transformed in the inte tine into a colorless product. When kept in a receptacle to which air cann gain access the same change occurs; the blue color readily returns on shakir the solution in the air. In alkaline solution the indigo loses its blue col and becomes greenish and then colorless. If acid be added the blue color r turns. If the alkali be allowed to stay in contact with the indigo for some tin the addition of acid does not bring back the color. When the indigo is e creted in an altered condition in the urine, as is the case when it is prese in small amount and when the urines are alkaline, the color cannot be broug back by the addition of acids. According to Voelcker the amount excret in the urine after an 80 mg. dose is 25 per cent., and the amount destroyed the body 75 per cent. Heidenhain showed that the indigo-carmin is excret by the cells of the convoluted tubule and the ascending loop of Henle. T amount of indigo excreted is certainly not dependent on the amount of polyuri

Type of Excretion.—Voelcker particularly notes the time of onset secretion, the time of greatest concentration, and the time of disappearan He states that in healthy individuals the color appears in from 3 to 5 minut that the greatest intensity of coloration is reached between a half and thr quarters of an hour (he takes care that a polyuria is not present by keepi the patient off of water and food for several hours before the examinatio that within the first two hours most of the excretion is over, although dim ishing amounts may be found as late as 12 hours. The type of the excreti varies with the amount given; when large doses, 160 mg., are given, the great excretion is within the first 30 minutes, and more than one-quarter of the to amount excreted is obtained in this period. The total excretion after 160 m dose is from 40 to 50 mg. After giving 80 mg. the greatest excretion is ste ily in the second and third half hours, when one-half of the total amount to excreted is put out. At least 85 per cent. of the total amount to be excret is put out in the first two hours. After the third hour the amounts are ve small. Voelcker regards the time of onset of secretion of great importan He states that this normally occurs in from 3 to 8 minutes. Under normal co ditions where polyuria is prevented after the 80 mg. dose the concentrati of the urine should reach at least .02 per cent.

In cases of renal insufficiency the time of onset is delayed and the amou

excreted, both from the percentage and absolute standpoints, is greatly reduced. In chronic interstitial nephritis, of which he reports two observations, the blue appeared in from half an hour to an hour; the amount not given, but very small. In a case of parenchymatous nephritis with marked edema the time of appearance was normal and the percentage quite normal. It is worthy of observation, however, that the total amount excreted was much smaller than in the cases of normal kidneys (see Voelcker, *loc. cit.*, p. 53). It is of interest that he does not call attention to this fact himself. He has noted poor and delayed excretion in cases of congenital cystic kidney, pyonephrosis, double infected kidney in association with prostatic hypertrophy, cases of infected double hydronephrosis, etc. In tubercular kidneys there is often no excretion of the blue, while on the other side it may be well excreted. He has used the total excretion in milligrams to reckon the total function, and has pointed out that marked reduction below the normal output is likely to mean serious insufficiency. In six observations of stone kidneys he noted delayed excretion and diminished excretion of the substance; and in a number of cases of hydronephrosis due to obstructions in the ureter, complete absence or great reduction of the amount of blue on the diseased side. The reduction is always marked in the case of pyonephrosis and the blue is frequently entirely absent. In 6 cases of kidney tumor the blue was equal on the two sides. In the four remaining cases there was marked functional disturbance. In the two cases where there was no disturbance the condition was hypernephroma at the upper pole. In both cases there was much normal parenchyma. Suter (*Ztschr. f. Urol.,* 1908, ii, 433) has employed the test clinically in a number of cases and is very much in favor of it. According to his experience 93 per cent. of all normal cases begin excreting in the first 12 minutes, and 7 per cent. are delayed beyond 15 minutes. Out of 26 normal cases the blue began at the same time on each side in 20 minutes. The longest difference noted between the two kidneys was 5 minutes. Petroff and Pereshivkin (*Russk. Vrach,* 1908, vii, 109; 151) have noted in experimental work on dogs and rabbits the following facts: The type of excretion is constant; on removing one kidney the second kidney does as much as both. Diffuse parenchymatous changes are followed by diminished and delayed excretion. Circumscribed changes often produce no alteration. If one kidney be removed and the other injured by injecting alcohol into it, there would be always a temporary and in some cases a permanent loss of power to secrete the blue. Even when the blue was permanently absent the animal still lived. M. Roth (*II Kongress d. Dtsch. Gesellschaft f. Urologie, Ztsch. f. Urologie,* 1909, *Beiheft* 2, 305) reports two cases of kidney stone associated with colic in which no blue was excreted, and yet

operation showed healthy kidneys. The opposite kidneys in these two cases secreted quite normally.

Personal Observations.—We have found considerable variations in the indigo-carmin products which we have used. The reason for this is not clear, as in every case it has been the Merck preparation. With most of our specimens we have been able to duplicate the experiences of Voelcker in every way. In some cases, however, while the total excretion has remained about the same in amount, it has been greatly prolonged, the maximum excretion in a healthy adult not being reached until the third hour, and considerable amounts being put out up to the 48th hour. With the exception of the results obtained in these prolonged excretions dependent on the dye, as proven by giving it to persons previously given other specimens, our results have been as follows: In normal adults, in the first hour, the output has varied from 5 to 17 per cent. In the second hour, from 4 to 6.4 per cent. In the third hour, from 1.2 to 4 per cent. The total three-hour output has varied from 16 per cent. to 22.6 per cent. In every case the first hour's output has been 50 per cent. or more of the total.

In bilateral renal infections there is a marked decrease in most cases in the indigo-carmin output. Take, for example, the case of Mrs. S., April 19, 1911. This patient had an old interstitial nephritis, as evidenced by the heart, the blood pressure, and the character of the urine. In the first hour her output was 2 per cent.; in the second hour .6 per cent.; all night 1.8 per cent. Or the case of Mrs. F., Feb. 28, 1911, where there was evident renal insufficiency associated with nausea, vomiting, and infection of both kidneys. Here the output in the first hour was .14 per cent., in the second hour .11 per cent., and in the third hour .2 per cent. In another acute nephritis with uremic symptoms, Mrs. P., July 6, 1910, the output was still smaller, .039 per cent. in the first hour, .045 in the second hour, and .023 in the third hour. Not all bilateral cases, however, show decreased output; in the case of Mrs. R. S., with double pyelitis and early pregnancy, the output for the first hour was 14 per cent., for the second hour 6.4 per cent., and for the third hour 2.2 per cent. In a mild parenchymatous nephritis, associated with albumin and casts, Mrs. E., May 2, 1910, the first hour showed 13 per cent., the second hour 7 per cent., and the third hour 2.6 per cent. In the retentions associated with prostatic hypertrophy there is a marked decrease. For example, in the case of Mr. C., April 18, 1910, 200 residual urine, with pus, the first hour showed 1.5 per cent. and the second hour .75 per cent.

The time of the appearance of the color varied from 5 to 15 minutes in normal cases, and in a few nephritic cases from 5 to 30 minutes.

Phenolsulphonephthalein Test.—Great interest has been excited among urologists in this country by the phenolsulphonephthalein method, introduced by Rowntree and Geraghty (*Jour. Pharmacol. and Exper. Therap.*, 1910, i, 579). It has certain distinct advantages over the other ones and an equal virtue with them in all respects. Its advantages are: (1) That it can be given in small doses; (2) that it is very rapidly eliminated; (3) that its detection and quantitative estimation in the urine is easy. It is likewise non-toxic and non-irritating.

The drug was first made by Ira Remsen (*Amer. Chem. Jour.*, 1884, vi, 208). Its pharmacological properties have been carefully studied by Abel and Rowntree. It is non-toxic, doses of a gram or more producing no untoward symptoms in animals. Whether taken by mouth or subcutaneously it is excreted by the kidneys. In large doses it is excreted in the bile, as well as in the urine, but that which passes in bile into the intestine is reabsorbed and excreted in the urine. It occurs as a crystalline powder and is readily soluble in solutions of sodium carbonate. The standard solution advised by Geraghty and Rowntree contains 6 mg. of the salt to each c. c. of fluid.

Technique of the Test.—Patient should be given intramuscularly, preferably into the muscles of the back, 1 c. c. of the solution. Subcutaneous injections are not so accurate as intravenous and a little more difficult. It can, however, be given by any of these methods. Before giving the phenolsulphonephthalein it is of advantage to produce some polyuria by having patient drink several glasses of water. The polyuria in no way increases the secretion of the phthalein, but it does guarantee that the amount discovered will more accurately represent the amount excreted. If only a few c. c.s are excreted in a given length of time, of a very concentrated nature, enough may be retained in the pelvis of the kidney or in the bladder to give too low readings.

The authors advise that a catheter be left in the bladder during the entire examination. We have not found this to be necessary if there is no retention.

They have used the DuBoscq colorimeter in estimating the amounts of the drug excreted, though we have used the instrument described for reading indigo-carmin. With either method it is possible to read accurately within 1 per cent. The color of the urine often leads to a reddish tint, which can be corrected by adding urine drop by drop to the standardizing solution (see p. 317).

Experimental Results.—Rowntree and Geraghty state that in 21 normal cases the time of the appearance of drug varied from 5 to 20 minutes. The percentage of the excretion in the first hour is from 40 to 60 per cent.; in the second from 20 to 25 per cent. In three cases of acute nephritis 44 per

cent. was excreted in the first hour, 4.8 per cent. in the second, and 19.4 per cent. in the third. In these cases the time of appearance varied from 22 to 23 minutes. In eight cases of chronic parenchymatous nephritis the time of appearance ranged from 10 to 25 minutes, and the amount eliminated from 10 to 52.5 per cent. In 10 cases of chronic interstitial nephritis the output in the first hour varied from a mere trace to 37 per cent. In hypertrophied prostatic trouble, where the patients were not using catheters regularly and where there was large residual urine, the output was very greatly reduced. In some cases the mere continuous drainage of the bladder by a catheter in the urethra led to rapid increase in the amount put out in the hour, some cases going all the way from 8 per cent. to normal. They noted that in many of these cases the output of the urea and other solids of the urine was normal. With an excretion of less than 20 per cent. in the first hour, they believe operation should be postponed. They insist that it is not a permanent low output, but one lowered for the time being and improving on drainage, which indicates renal insufficiency. In addition to this study of total renal function the authors have devoted considerable time to a comparison of the two kidneys. In general a diseased surgical kidney puts out less of this substance than a healthy one.

Schmidt and Kretschmer (*Trans. Am. Urol. Ass.,* 1911, v, 233) report as follows:

In 16 normal individuals the percentage of excretion in the first hour varied from 20.46 per cent. to 60.975 per cent., and in the second hour from 8.77 per cent. to 37.87 per cent.; the total output for 2 hours varied from 47.13 per cent. to 71.52 per cent. In twenty-two prostatic cases the authors noted that the excretion in the first hour varied from 14.05 per cent. to 64.91 per cent., and during the second hour from 7.3 per cent. to 26.59 per cent., and for the 2 hours the excretion varied from 29.15 per cent. to 74.725 per cent. In one case, resulting fatally, they noted that while the total excretion was good—nearly 60 per cent. in total—the kidneys did not begin to excrete for an entire half hour. They hold that it is not the time of appearance but the total excretion that is of importance. Testing with phenolsulphonephthalein, indigo-carmin, and phloridzin as to the time of reaction in the urine, in eight cases they found the substances all showed the same variations. In several cases urine was collected for 3 hours, and they hold that the even excretion for 3 hours of almost identical amounts indicates that the kidneys are working at their top and are badly damaged. In 20 cases where the dye was administered intravenously the first hour output varied from 31.34 per cent. to 79.46 per cent.

Cabot, of Boston, in discussing this paper, quotes 3 cases of interstitial nephritis, in which the drug excretion did not correspond with the general condition of the patient. In one, where general health seemed fair, the drug was excreted only 4 per cent. in the two hours; in another, with all the signs of chronic nephritis, the two hours' secretion was 60 per cent. At autopsy, immediately after death, the kidneys were found extensively diseased. In another case a child quite ill gave an excretion of 50 per cent. in two hours.

R. M. Smith (*Archv. of Internal Medicine,* 1911, viii, 481) has reported some interesting results in the excretion of the drug in rabbits, both normal ones and those in which there had been produced a nephritis. In normal rabbits the excretion in the first hour is about 40 per cent., corresponding to Geraghty and Rowntree's findings in human beings. In some of the cases of nephritis the excretion of the drug is decreased and in others it is not decreased. There is no correspondence between the excretion of the drug and the microscopical appearance of the kidney. In some cases where the drug excretion is decreased the kidney anatomically looks better than others where there was no decrease in the excretion of the drug.

Personal Observations.—We have observed the excretion of phenolsulphonephthalein in quite a long series of patients. In addition to giving the drug to those known or suspected to be suffering with some disease of the urinary organs, we have given it to a large number of perfectly healthy people and also to some others with troubles elsewhere, but with no apparent disease of the kidneys. In these normal cases there has been marked variation in the time of the appearance of the drug—from 4 to 15 minutes. The output for the first hour has varied from 7.5 per cent. to 63 per cent. The second hour shows wide variations. The total output has varied greatly. The type of excretion has been very different. In some cases the total output has occurred within 2 hours. This has been the case in patients with high outputs as well as those with low outputs. We have observed that in some patients with whom the total output was identical, excretion would be complete in one case in 2 hours, while in another it would continue for 4 or 5 hours. The same healthy individual under the same conditions, but at different times, shows marked variations; for example, one of us (Burnam) showed different outputs by the hour at 5 different dates. These are shown in Table I in cases 2, 11, 18, 20, and 38. The condition of the experiments at these different times was identical except for the fact that on the date of February 9, Observation 20, in addition to the phenolsulphonephthalein the author produced a polyuria by taking three bottles of Apollinaris water and 30 gr. of caffein. Caffein apparently inhibits the excretion of phenolsulphonephthalein to some extent.

This is shown in Observations 19 and 21, on the latter day caffein being given. The subject was the same in each case. The variations in output are well shown in Table I, which consists of 85 successive observations in 80 individuals. All of these patients were either entirely healthy or without kidney trouble; possibly the cancer of the cervix cases should be excluded from the list. Compare Table I with Table II, which includes a series of patients with definite or suspected kidney trouble, and it is at once evident how the normal and the diseased conditions overlap. In this Table II are 45 cases in which there was not marked clinical evidence of renal insufficiency, but nevertheless definite disease of the kidneys. We have observed a half dozen cases of chronic interstitial nephritis in which there was scarcely any output. All of these have terminated fatally. We have also observed several cases of marked bilateral renal infections with evident renal insufficiency and a very low output. It is not possible by the output to distinguish definitely between a functional albuminuria and a nephritis. This was shown in case 12, Table II. The output, as noted, is very good. A month previous to this observation this patient was first tested and found to show essentially the same conditions, so far as phenolsulphonephthalein excretion is concerned. The condition was put down as functional albuminuria.

In all the observations recorded in Table I and II the technique was the same. One c. c. (6 mg.) of phenolsulphonephthalein was injected and collection made by the hour from the time of the injection. In reading, a standard solution was made with the same syringe used for injection. The graduations upon the syringes in general use are not accurate, and each syringe should be carefully standardized. This includes the record as well as other syringes. The readings were made with the same apparatus as used for the indigo-carmin (see p. 316).

TABLE I—NORMAL CASES

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
1. Mr. G Mar 25, 1911 24 yrs.	Infected hand.......	37%	25%	
2. Dr. B Mar. 26, 1911 34 yrs.	Normal............	24%	44%	
3. Dr. S. Mar. 26, 1911 44 yrs.	Normal............	38%		
4. Dr. W. Mar. 26, 1911 36 yrs.	Normal............	50%	23%	

TABLE I—NORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
5. Dr. J. Mar. 26, 1911 39 yrs.	Normal............	63%	20%	7%
6. Mrs. M. Mar. 31, 1911 50 yrs.	Healthy looking but neurasthenic woman	42%	23%	
7. Mr. J. W. Apr. 6, 1911 Young adult	Healthy............	40%	20%	
8. Mrs. B. Apr. 11, 1911 28 yrs.	Pregnancy, normal; fourth month......	25%	26%	
9. Mrs. H. Mar. 24, 1911 Middle aged	Ovarian neuralgia....	58%		
10. Mrs. C. A. C. Nov. 15, 1910 29 yrs.	Movable left kidney..		Total—2 hrs. 28%	
11. Mr. C. F. Nov., 1910	Normal............		Total—2 hrs. 51%	
12. Mrs. W. M. Nov. 18, 1910 36 yrs.	Pelvic adhesions.....		Total—2 hrs. 35%	
13. Miss A. M. Dec. 2, 1910 38 yrs.	Movable right kidney, abdominal adhesions............	30%	21%	18%
14. Mrs. A. G. B. Jan. 16, 1911 25 yrs.	Normal............	23.5%	13.5%	
15. Mrs. A. G. B. Jan., 1911 25 yrs.	Normal............		Total—2 hrs. 48%	
16. Mrs. E. L. M. Jan., 1911 37 yrs.	Normal............	1½ hrs. 38.5%	19.2%	
17. Mrs. J. F. C. Jan. 31, 1911 43 yrs.	Urethritis..........		Total—2 hrs. 42.5%	
18. Mr. C. B. Feb. 8, 1911	Normal............		Total—2 hrs. 31.6%	9.5%
19. Dr. J. B. Feb. 8, 1911	Normal............		Total—2 hrs. 58.8%	13%
20. Mr. C. F. B. Feb. 9, 1911	Normal............	13.8%	24%	3rd hr. and ½ 18.5%
21. J. B. Feb. 9, 1911	Normal............	19.4%	33.7%	
22. Mrs. L. W. Feb. 24, 1911 50 yrs.	Cancer of the stomach	45%	32%	
23. Mrs. C. C. March 3, 1911	Neurasthenia........	22%	7%	4.2%
24. Miss E. H. Apr. 1, 1911 33 yrs.	Neurasthenia; intestinal adhesions......	32.5%	16%	12%
25. Mrs. M. R. Apr. 4, 1911 61 yrs.	Normal............	18.5%	20%	10%

TABLE I—NORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
26. Mrs. E. W. Apr. 5, 1911 36 yrs.	Dysmenorrhea, healthy individual. .	20%	20%	12.5%
27. Mrs. J. H. W. Apr. 7, 1911 50 yrs.	Normal.	47%	20%	10%
28. Mr. B. Apr. 12, 1911	Sacro-iliac joint.	49%		
29. Mrs. W. A. B. May 3, 1911 40 yrs.	Urine normal; retroflexion of uterus; R. V. O.	22%	23%	25%
30. Mr. McL. June 14, 1911	Heart trouble.	29%		
31. Mrs. J. H. L. June 14, 1911 63 yrs.	Nervousness; normal urine.	30%	15%	6.5%
32. Mrs. C. I. A. Oct. 17, 1911 56 yrs.	Cancer of breast.		Total—2 hrs. 50%	
33. Mrs. H. G. W. Oct. 21, 1911 31 yrs.	Headaches, due to eyes. Pelvic inflammatory trouble.	34%	15%	
34. Mrs. G. S. F. Oct. 23, 1911 34 yrs.	Retroflexion of uterus, relaxed outlet.	25%	18%	
35. Mrs. D. H. Nov. 7, 1911 26 yrs.	Painful menstruation.	20%	30%	
36. Mrs. P. L. Nov. 8, 1911 31 yrs.	Normal urine. Adherent tubes and ovaries. Healthy looking individual. .	13%	27%	
37. Miss S. K. Nov. 8, 1911 21 yrs.	Pain of probably spinal origin.	13%	15%	
38. C. F. Nov. 30, 1911	Normal.	28%	18%	20%
39. Dr. A. U. Nov. 30, 1911	Normal.	41%	23%	
40. Miss M. A. Dec. 14, 1911 17 yrs.	Chronic appendicitis.	52%	20%	
41. J. B. Dec. 4, 1911	Normal.	48%		
42. Mrs. C. H. W. Dec. 5, 1911 31 yrs.	Retroflexion of uterus, adherent appendix. .	25%	20%	8%
43. Mr. C. Dec. 6, 1911 27 yrs.	Normal.	38%	15%	
44. Mr. T. Dec. 6, 1911 33 yrs.	Normal.	15%	18.5%	
45. Mrs. H. Dec. 13, 1911	Normal.	25%		
46. Miss A. R. Dec. 11, 1911 46 yrs.	Double ovarian cyst; breast cyst.		Total—2 hrs. 24%	

TABLE I—NORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
Mrs. W. A. G. Dec. 19, 1911 [illegible] yrs.	Cancer of cervix uteri; normal urine.......	20%	13%	
Miss E. M. Jan. 9, 1912 45 yrs.	Neurasthenia	34%	7%	2.5%
Miss M. B. Jan. 10, 1912 46 yrs.	Uterine fibroids	20%	15%	4%
Dr. G. Jan. 11, 1912			2 hrs., 15 min. 44%	17%
Mrs. J. G. O. Jan. 20, 1912 30 yrs.	Frequent abortions. .	35%	7.5%	
Miss M. D. Jan. 24, 1912 28 yrs.	Normal urine; dysmenorrhea.........	11%	21%	2.5%
Mrs. W. P. Jan. 25, 1912 36 yrs.	Torn vaginal outlet. Torn cervix. Movable kidneys. Myomata uteri.........	44%	14%	
Mrs. W. A. Q. Feb. 7, 1912 34 yrs.	Retroflexed adherent uterus.............	26%	25%	
Mrs. J. P. H. Feb. 14, 1912 28 yrs.	Post-operative adhesions............	48.5%	27%	
Mrs. J. S. R. Feb. 14, 1912 44 yrs.	Tumor of the sigmoid.	30%	32%	
Mrs. R. L. Feb. 19, 1912 66 yrs.	Relaxed vaginal outlet................	25%	30%	
Mrs. F. B. S. Feb. 23, 1912		25%		
Mrs. A. M. Feb. 27, 1912 28 yrs.	Retroflexion of uterus, relaxed outlet......	7.5%	23%	
Mrs. W. P. Feb. 27, 1912 42 yrs.	Post-operative adhesions..............	23%	19%	
Miss A. C. Feb. 28, 1912 41 yrs.	Normal...........	28%	20%	
Miss S. B. Feb. 28, 1912	Papillary carcinoma of left ovary.......	28%	21%	
Mrs. I. H. March 4, 1912 64 yrs.	Ulcerated cervix; cystocele, R. V. O.....	24%	20%	
Mrs. W. W. C. March 9, 1912 52 yrs.	Polypoid endometrium; anemic........	13.5%	12%	
Mrs. A. P. S. March 11, 1912 43 yrs.	Infected ovarian cyst; hemorrhoid; infected appendix..........	20%	40%	
Mrs. J. F. S. March 13, 1912	Normal...........	35%	24%	

TABLE I—NORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
67. Mrs. E. T. March 17, 1912 36 yrs.	Normal............	35%	18%	
68. Mr. B. Mar. 18, 1912	Normal............	1½ hrs. 60%		
69. Miss S. Apr. 10, 1911 21 yrs.	Healthy young girl...	36%	24%	
70. Dr. G. W. 28 yrs.	Healthy man........	30%	22.5%	
71. Mrs. P. Feb. 1, 1912 35 yrs.	Retroflexed uterus. Apparently normal kidneys and bladder.	28%	12%	4%
72. Mr. A. S. Apr. 10, Young adult	Infected hand.......	26%	22%	
73. Miss C. Apr. 10, 1911 20 yrs.	Healthy girl........	42%	22%	
74. Mrs. T. Apr. 10, 1911 24 yrs.	Healthy woman.....	60%	14%	
75. Mr. J. T. McG. Apr. 10, 1911 40 yrs.	Vigorous man; no disease...............	22%	13%	18%
76. Miss G. B. June 21, 1911 37 yrs.	Normal............	13.5%	19%	9%
77. Miss H. K. June 21, 1911 54 yrs.	Normal urine; general weakness......	24%	15%	10%
78. Mrs. M. L. June 22, 1911 63 yrs.	Large tumor of the pelvis.............	15%		
79. Mrs. R. A. C. June 23, 1911 55 yrs.	Normal urine; urethral caruncle........	19%	20%	
80. Rev. R. A. W. June 25, 1911 53 yrs.	Normal urine; brain tumor.............	15%	16%	14%
81. Mrs. W. P. B. June 26, 1911 34 yrs.	Normal urine; patient nervous...........	18%	25%	17%
82. Mrs. Y. W. R. July 5, 1911 33 yrs.	Normal urine; neurasthenia and constipation..............	43.75%	35.75%	16%
83. Miss M. July, 1911 45 yrs.	Normal urine; fibroid uterus.............	15%	27%	17%
84. Mrs. H. Sept., 1911 45 yrs.	Cancer of the cervix..		Total—2 hrs. 14%	
85. Mrs. S. P. McC. Oct. 17, 1911 70 yrs.	Incontinence of urine, due to cystocele...		Total—2 hrs. 40%	

TABLE II—ABNORMAL CASES

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
1. Mr. W. W. S. Nov. 15, 1910 64 yrs.	Chronic cystitis.....		Total—2 hrs. 50%	
2. Miss C. E. Nov. 15, 1910 42 yrs.	Solitary kidney, one being removed for tuberculosis........	25%		
3. Miss A. S. Nov. 22, 1910 32 yrs.	Infected left kidney removed, normal right kidney	12%		
4. Miss A. S. Jan. 13, 1911 32 yrs.	Infected left kidney removed, normal right kidney.......	29.8%	17.2%	
5. Mrs. W. C. B. Jan. 13, 1911 43 yrs.	Tubercular left, normal right kidney ...	15.28%	12.26%	
6. Miss E. A. Jan. 25, 1911 21 yrs.	One kidney removed for tuberculosis, the other normal.......		Total—2 hrs. 43.02%	
7. Mrs. W. R. A. Feb. 21, 1911 50 yrs.	Stone in right kidney.	18%	18%	9%
8. Mr. J. M. M. Feb. 24, 1911 58 yrs.	Definite interstitial nephritis..........	7%	18%	
9. Mr. J. M. M. Mar. 1, 1911 58 yrs.	Definite interstitial nephritis..........	7%	14%	6%
10. Mrs. M. F. Feb. 28, 1911 51 yrs.	Interstitial nephritis and infected kidneys. Double papilloma of ovaries.....	6.25%	15%	2.6%
11. Mrs. W. H. S. Mar. 3, 1911 35 yrs.	Nephritis...........	12%	20%	16%
12. Mr. T. Mar. 17, 1911 20 yrs.	Albuminuria and casts..............	52%	11%	14%
13. Mrs. M. F. Mar. 27, 1911 51 yrs.	Interstitial nephritis and infected kidneys. Double papilloma of ovaries.....	6.8%	21%	16.5%
14. Mrs. W. H. S. Apr. 1, 1911 35 yrs.	Nephritis...........	11.6%	22%	15%
15. Mrs. H. S. R. Apr. 5, 1911 67 yrs.	Interstitial nephritis..	20%	15%	10%
16. Mr. P. Apr. 14, 1911	Pyelitis, double......	7%	16.4%	13.1%
17. Miss C. E. May 24, 1911 42 yrs.	Solitary kidney, one being removed for tuberculosis........	18%	24%	17%
18. Mr. P. May 24, 1911	Pyelitis, double......	18%		
19. Mrs. McC. June 5, 1911 49 yrs.	Irritable bladder.....	10%	14%	7%

TABLE II—ABNORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
20. Mrs. A. J. June 13, 1911	Bilateral kidney stones............	25%	16%	7.2%
21. Mrs. F. H. June 23, 1911	Cystic left ovary, gall stones, R.V.O., trace of albumin, no casts.	17%		
22. Mrs. P. H. Oct. 18, 1911 53 yrs.	Nephralgia, bilateral.		Total—2 hrs. 73%	
23. Mr. J. M. R. Oct. 20, 1911 43 yrs.	Gall bladder infection; albumin and casts.............	16.5%	17%	
24. Mrs. A. M. W. Oct. 20, 1911 31 yrs.	Urine: traces of albumin and pus cells. No casts. Ovarian cyst, retroflexion of uterus, complete tear.............	35%		
25. Mrs. H. B. P. Oct. 20, 1911 47 yrs.	Uretero-vaginal fistula, right; infected right kidney.......	11.5%	12%	
26. Mrs. R. L. W. Oct. 24, 1911 39 yrs.	Exfoliative pyelitis...	25%	23%	
27. Mrs. F. LaM. Nov. 8, 1911 61 yrs.	Mental aberration, cystitis............	12%	17.5%	
28. Mrs. R. T. Nov., 1911 22 yrs.	Bilateral kidney stones............		Total—2 hrs. 20%	
29. Mr. W. VanD. Nov. 21, 1911 36 yrs.	Cystitis. Appendectomy.............	10%	20%	
30. Mrs. M. B. Nov. 27, 1911 34 yrs.	Stone in left kidney..	22%	16%	
31. Mrs. A. T. McD. Jan. 29, 1912 28 yrs.	Tuberculous kidney removed, remaining kidney normal.....	In 40 min. 7.5%	10%	6%
32. Mrs. W. N. F. Jan. 30, 1912 68 yrs.	Acute cystitis.......	Urine lost	34%	17%
33. Mr. A. H. Feb. 4, 1912 34 yrs.	Pain in renal region..	30%	22%	
34. Mrs. L. R. G. Feb. 9, 1912 46 yrs.	Stone kidney removed	40 min. 21%	33%	
35. Mr. C. A. C. Feb. 21, 1912 49 yrs.	Cystitis...........	15%		
36. Mrs. E. C. S. Feb. 29, 1912 29 yrs.	Bilateral pyelitis; bilateral hydronephrosis...............	15%	23%	
37. Mrs. A. T. McD. Mar. 12, 1912 28 yrs.	Tuberculous kidney removed..........	22%	15%	

TABLE II—ABNORMAL CASES—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
38. Mrs. Chas. T. Mar. 14, 1912 67 yrs.	Gall-stones.........	20%	14%	
39. Miss J. R. Mar. 15, 1912 45 yrs.	Normal right kidney. Left kidney removed	15%	21%	20%
40. Mrs. T. E. C. Mar. 17, 1912 61 yrs.	Stone in ureter......	11%	8%	
41. Mr. B. F. Sept. 22, 1911 50 yrs.	Irritable bladder....	67.5%		
42. Mrs. S. Sept. 27, 1911 75 yrs.	Gall-stones.........	44%	30%	
43. Mrs. G. Sept. 28, 1911 42 yrs.	Pain in left kidney...		Total—2 hrs. 40%	
44. Mr. P. Jan. 26, 1912 40 yrs.	Interstitial nephritis; albumin and casts..	40%	12%	16%
45. G. H. Mar. 25, 1911 7 yrs.	Acute nephritis; mitral insufficiency....	24%	31%	
46. Rev. T. Mar. 28, 1911 45 yrs.	Albumin and casts; good general cond..	55%	18%	
47. R. S. Apr. 5, 1911 18 yrs.	Cured acute nephritis	60%		
48. A. T. Apr. 9, 1911 60 yrs.	Interstitial nephritis; albumin and casts..	40%		
49. Mr. M. C. C. Mar. 21, 1911 60 yrs.	Pyelitis right, cystitis................	40%	25%	
50. Mr. C. Mar. 24, 1911 45 yrs.	Infected stone kidney, right..............	39%	40%	10%
51. Mr. Wm. C. Apr. 18, 1910 65 yrs.	Enlarged prostate....	26%	15%	

TABLE III—COMPARISON BETWEEN EXCRETION OF INDIGO-CARMIN AND PHENOLSULPHONEPHTHALEIN

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
1. Mr. C. April 18, 1910 65 yrs.	Enlarged prostate....	Thal. 26% Ind. 1.5%	Thal. 15% Ind. .75%	
2. Dr. C. F. B. April 28, 1911	Normal............	Thal. 28% Ind. 14%	Thal. 18% Ind. 6.4%	Thal. 20% Ind. 2.2%

TABLE III—COMPARISON BETWEEN EXCRETION OF INDIGO-CARMIN AND PHENOLSULPHONEPHTHALEIN—*Continued*

Initials Date Age	Condition	1st Hour	2nd Hour	3rd Hour
3. Mrs. R. May, 1910 33 yrs.	Normal............	Thal. 43.75% Ind. 10%	Thal. 33.75% Ind. 4%	Thal. 16% Ind. 2%
4. Mr. P. May 24, 1911 50 yrs.	Interstitial nephritis; double pyelitis.....	Thal. 18% Ind. 2%		
5. Mrs. F. Feb. 28, 1911 51 yrs.	Interstitial nephritis; bilateral infection of the kidneys.........	Thal. 6.25% Ind. .14%	Thal. 15% Ind. .11%	Thal. 4.5% Ind. .2%
6. Mrs. S. Apr. 1, 1911 35 yrs.	Old parenchymatous nephritis..........	Thal. 11.6% Ind. 2%	Thal. 22% Ind. .6%	Thal. 15% Ind. 1.8%

In a number of cases, amounting in all to twenty-three, comparisons were made with the excretions of indigo-carmin and phenolsulphonephthalein. In each case one c. c. of the standard phenolsulphonephthalein was given. When its excretion was ended twenty c. c. of indigo-carmin was given. The excretion in six of these cases is shown in Table III. One will observe at once that, while in a general way corresponding, the types of excretion vary materially. Note in the two normal cases how much more phenolsulphonephthalein is excreted in No. 3 than in No. 2, while as to indigo-carmin the reverse is true. From this little table one also appreciates that phenolsulphonephthalein has considerably more power in passing a diseased kidney than the indigo-carmin. Observations like this lead us to the conclusions of Lépine, working with methylene blue and rosanilin, "each dye has its own specific coefficient of excretion." We have had no personal experiences with rosanilin, but, judging by the reports of Dreifuss, we would conclude that rosanilin, phenolsulphonephthalein, and indigo-carmin are inhibited in passing through diseased kidneys and that the rosanilin goes through the most readily, the phenolsulphonephthalein next, and the indigo-carmin poorly. All of this is intimately connected with the physiology of the kidney. As already mentioned, caffein, which increases the excretion of sodium chlorid and urea, decreases phenolsulphonephthalein excretion.

General Conclusions.—Up to the present time we have no means of quantitatively estimating whether the kidneys are capable of carrying on their work satisfactorily under strains. A general clinical examination enables ready appreciation of whether there is marked insufficiency. It is the border-line cases and compensated cases which leave us in the dark. It is quite certain that the dye tests are all much interfered with and permanently so in interstitial

nephritis, and that complete absence or very low excretions are associated with active insufficiencies. We have never observed a high excretion of indigo-carmin or phenolsulphonephthalein in cases of marked renal insufficiency. We believe, therefore, that their use will demonstrate that conditions of coma or deep intoxication are not of renal origin, when if this drug be given, it is found to be abundantly excreted. We saw recently a case of this kind in which a very good medical man insisted that the condition was renal; phenolsulphonephthalein was abundantly excreted and the actual condition was a cerebral thrombosis.

On the other hand, low excretion and especially moderately low, leave one in the dark.

The dyes are markedly interfered with in their excretion in cases of urinary obstruction at any point in the tract below the kidney and likewise in infections. The most brilliant example of this is afforded by the cases of prostatic hypertrophy with retention. In such cases phenolsulphonephthalein or indigo-carmin, while not showing the actual functional condition of the kidney, do serve as splendid indicators of improvement under treatment. The phenolsulphonephthalein makes it possible in these cases to detect renal insufficiency, which cannot be made out by any of the other functional tests, with the exception of indigo-carmin. The development of this fact, which has a far-reaching influence in prostatic surgery, we owe to Doctors Geraghty and Rowntree. By the use of the phenolsulphonephthalein it is possible to avoid needlessly long preparatory drainage of the bladder in some cases, and in others to postpone procedure where the recovery is slow.

The dye tests are of immense value in studying improvements in all types of kidneys with impaired function. While, therefore, our tests do not enable us to judge perfectly in any one case, they do afford an enormous assistance. They are just like all other clinical tests in helping to complete the picture necessary for prognosis and diagnosis.

While it is impossible to accurately judge of the efficiency of total renal excretion, very interesting and valuable studies can be made by comparing the functions of the two kidneys in an individual by separately catheterizing the ureters. Under usual conditions the two kidneys receive the same kind of blood and in the same quantities. It would seem, therefore, that an estimation of their outputs in units of time would afford data for determining what proportion of the work each does. It is certainly true that studies of this kind have yielded us more knowledge as to the renal function than any other form of study. It is to the late J. Albarran, whose wonderfully clear and careful work in all the field of urology is distinguished, that we owe our principal

stimulus in this direction. In studying the separated urines it should be kept in mind that no one constituent of the urine or all of them together can actually picture absolute values, and that it is very absurd to speak of one kidney as having twice or three times the functional capacity of its fellow. The problem does not submit itself to any such arithmetic formulæ.

ESTIMATIONS OF THE FUNCTIONS OF THE TWO KIDNEYS SEPARATELY.

All the methods employed and described for estimating the total renal function are applicable in this connection. For many years in the clinic at the Johns Hopkins Hospital we have been in the habit of comparing the amount in fluid, urea, and specific gravity for periods of from ten to twenty minutes. Since the appearance of Albarran's valuable contribution and the indigo-carmin and phenolsulphonephthalein tests we have been in the habit of collecting for an hour at the shortest, and in some cases for two or three hours.

The Questions of Technique.—In order to do effectual functional test examinations certain precautions must be taken. The first of these is the use of catheters of sufficient size to plug the ureters so that there is no flow of urine around the catheter. This is easily accomplished in the female with the Kelly cystoscope. In some cases it is necessary to use a very large catheter. The fluted end catheter of Albarran is of distinct advantage here. Recently there have been introduced a number of cystoscopes of the Nitze type which will carry very large catheters. A typical collection is shown in Chapter X.

The method which we have employed for many years to determine that there has been no reflux is, at the time of the collection, to inject a deeply colored fluid through the catheter into the pelvis of the kidney when the collection is just over. If there is reflux this will appear in the bladder. Quite satisfactory results can be obtained by catheterizing one kidney and collecting the urine transvesically (Fig. 158). In such cases, however, great care should be taken to see that the bladder is thoroughly emptied, before collection begins and before it ends. During the collection there should be continuous watch to see that the catheters are properly draining. When it is desired to study the influence of water in producing a polyuria, the tubes in which the urine is being collected should be changed at fifteen-minute intervals.

Disagreeable Sequelæ of Functional Tests.—We have never seen any serious complications result from leaving the catheters in for an hour or more. In a number of cases we have left them in for four or five hours. In one patient

with a solitary kidney and a carcinoma nodule pressing on the ureter the catheter was left in for more than two weeks without discomfort. However, in nearly all cases a certain amount of blood will result from leaving the catheter in for an hour or more. Occasionally a patient will not tolerate the catheter. In nearly all cases severe renal colic follows within five or six hours. This is so distressing at times as to be quite upsetting both to the patient and to the operator. After one of these collections it is well to have the patient under observation for at least 24 hours. This severe colic is rarely met with after collections of from ten to fifteen minutes. It almost invariably follows collargol injections.

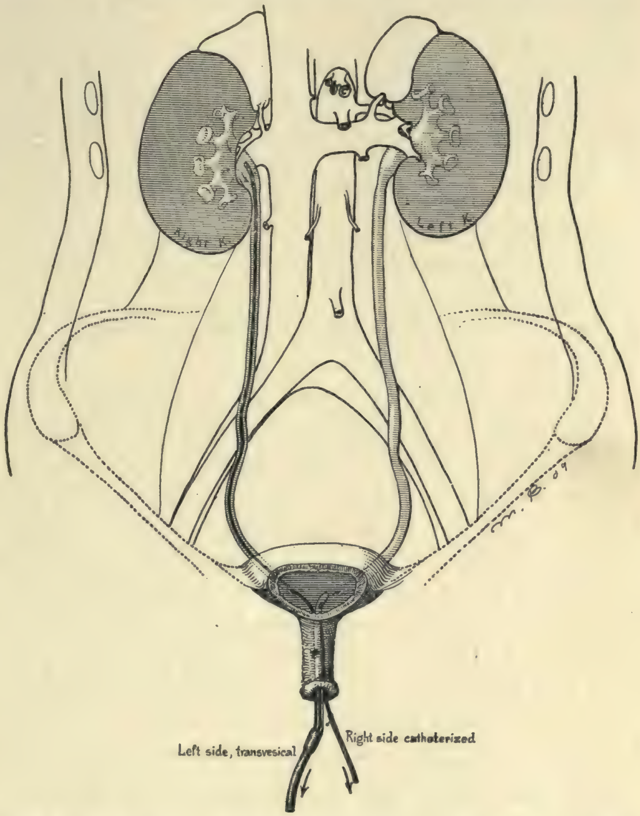


FIG. 158.—SCHEMATIC REPRESENTATION OF HOW THE URINE FROM EACH KIDNEY CAN BE COLLECTED SEPARATELY, WITH ONLY ONE URETER CATHETERIZED. Urine from the left kidney runs through the bladder and out the urethral catheter. A catheter of sufficient size to plug the ureter and prevent back-flow must be used.

The Tests. — It is possible in the same examination to combine a number of tests; for example, the quantity of urine, its specific gravity, its freezing point, the amount of urea, the amount of sodium chlorid, the phosphates, and the amount of phenolsulphonephthalein can be readily determined. It has been our experience that the phloridzin test cannot be combined with the color test. The color tests interfere with the secretion of sugar,

and the phloridzin to some extent inhibits the color. This test should, therefore, not be used. In addition it is possible to combine the experimental polyuria test worked out by Illyés and Kevesi (*Berl. klin. Wchnschr.,* 1902, xxxix, 321) and popularized in connection with the catheterization of the two kidneys by Albarran ("Exploration des fonctions rénales," Paris, 1905). This test depends on the fact proved by Albarran that a healthy kidney shows a remarkable power to vary the concentration of the urine it secretes, i. e., when deprived of fluid a healthy kidney secretes a small quantity of highly concentrated urine. When fluid is given it can secrete a larger quantity of dilute urine. In contradistinction to this healthy kidney, a kidney in which there is interstitial nephritic change, and such is the change with most chronic surgical renal diseases, ordinarily secretes a considerable amount of urine of low specific gravity. In such a case the addition of fluid does not increase materially the amount of urine. It is as if the diseased kidney was working at its highest capacity while the healthy kidney has a reserve force.

Albarran originally advised the giving of several hundred c. c. of water and collection for three hours. E. L. Keyes (*Ann. Surg.,* 1910, li, 340) has pointed out that occasionally he is unable to get a polyuria. We have observed the same condition. In our experience, from one to two bottles of Apollinaris water given at the beginning of the test will show up plainly within fifteen minutes and reach its maximum in the fourth or fifth period of fifteen minutes. In addition to the water, as Albarran pointed out, phloridzin adds to the certainty of the polyuria. By means of polyuria the amount of fluid, the amount of urea, and the amount of sodium chlorid are increased. On the other hand, there is no increase in the dye output or in the output of phosphates. When it is realized that a polyuria alone can cause an increased amount of urea to be put out, it is evident that, if this specific polyuria test is not desired, it is nevertheless advantageous to cause a polyuria, so that both kidneys, the healthy and the diseased, are affected. If this is done the urea becomes probably the most valuable single element in the urine to gauge the comparative value of the kidneys.

Relative Functional Value of Normal Kidneys.—It was long held by physiologists that the kidneys did not secrete equally. This was based on comparisons in animals and upon a few cases of congenital exstrophy of the bladder. With the introduction of modern cystoscopy and catheterization of the ureters our views changed. Casper of Berlin was the first to assert that normally the two healthy kidneys secreted equally, in a given unit of time, usually about ten minutes. Casper's work was largely with phloridzin and a comparison of the sugar outputs of the two sides. Albarran was the first to emphasize, what

is now generally recognized, that healthy kidneys do vary in their outputs of fluids and solids. In ten-minute intervals there may be a 30 per cent. difference. In an hour's period, and in longer periods, this difference is greatly decreased.

In cases of this kind the difference is rarely over 15 per cent. in an hour. It is of interest that the variations are not always in the same direction; that is, in a unit of time one kidney will put out more urea but less phthalein; the Δ V may not vary in the same direction as the sugar after phloridzin. The quantity alone is not of much value. A few examples of this variation in normal cases are shown at the end of the chapter.

The Function Value of the Diseased Kidney as Compared to the Healthy.—In general, unilateral disease of the kidney is associated with a decrease in its functions. There are many variations; for example, an early tuberculosis with tubercle bacilli and pus may involve such a small part of the kidney that there is no decrease in the function. This is a condition not infrequently observed with renal tumors and with pyelitis. On the other hand, it is possible and is frequently observed that with normal urine there is distinct and wide variation. Such a variation is a sign-pointer to disease, though it does not tell what the disease is. It should be borne in mind in considering infections, obstructions, and the like conditions that the kidneys can improve remarkably after relief of the disease. In other words, a kidney under such circumstances should not be condemned as worthless because at the time of examination its function is poor. We have observed repeatedly in cases of chronic infection of the kidney, associated with obstruction of one kind or another, that on removing the kidney it can be demonstrated to have an abundance of renal parenchyma.

Of the various constituents water is most likely to be least affected in the surgical diseases. Next comes sodium chlorid, and then urea. It is our impression that of all the single tests urea gives the best idea, so far as the function is concerned, in the comparisons. The mere fact that our means of estimating the urea are not absolutely accurate does not militate against the test, as the inaccuracy under the same conditions varies in the same direction, and it is not the absolute amount but the relative that we have in view. The dyes exaggerate differences and phloridzin does so still more. Indigo-carmin is a greater exaggerator than phenolsulphonephthalein. It is well before making a comparative test of the kidneys to estimate the total output of phthalein or indigo-carmin. In some cases we have noted a marked variation in the outputs without catheterizing ureters and with the catheters seeming to inhibit the output. An interesting observation of this kind was made by us about a

year ago. The patient in this case is a healthy woman. About ten years ago she was under treatment for an ulcer of the bladder, which was excised and found to be tubercular. At that time the ureters were repeatedly catheterized and no evidence of tuberculosis found. The case was regarded as a primary vesical tuberculosis. She was in the habit of reporting at intervals for examination. On this visit we catheterized the kidneys and made a functional test, and found the left kidney much less efficient than the right. This finding we interpreted as a healed tuberculosis of the left kidney.

Value of the Comparative Estimations.—As already pointed out, one of the chief values of the functional test is diagnostic. It may point to a difference not noted otherwise. It leads to the recognition of renal trouble and distinguishes it from trouble elsewhere. A case, for instance, like this recent one is suggestive. A mass was present in the right side, evidently a neoplasm. The total output of phthalein was high. The output from the two sides was identical. The kidney pelvis was normal. On this finding the diagnosis was made of probable extra-renal tumor. Such operation proved to be the case. Had this kidney been markedly less in function than its fellow, the tumor would almost certainly have been renal. This is, however, not necessarily so. In one very interesting case of a tumor of soft cystic nature the size of a child's head in the upper left quadrant of the abdomen, the urine was found normal, the two kidneys were found to be actively secreting, but the left showed considerable reduction in function. This finding, in combination with the other examinations, led to the belief that we were dealing with a pancreatic tumor pressing on the vascular pedicle of the left kidney. This was confirmed by operation, where a cyst in the tail of the pancreas was found.

The functional tests are of value, and great value, in deciding whether it is best to remove a diseased kidney. Countless operations have shown that one of two healthy kidneys can be removed without danger to the patient. With still greater safety a thoroughly diseased kidney can be removed, for in such cases the healthy kidney has undergone a compensatory hypertrophy. It has been repeatedly observed that the removal of an infected kidney, which is causing through its general intoxication a nephritic process in the other kidney, is followed by marked improvement in the power of the healthy kidney to excrete the dyes, and particularly to produce sugar after giving phloridzin. For this reason it is not well in conditions which are imperative, as renal tuberculosis or neoplasm, to postpone operation and to do nephrectomy. On the other hand, in ordinary pus kidneys under such circumstances it is better to do a conservative operation, e. g., incision and drainage, and to await results. With an interstitial nephritis on one side and a surgical kidney on the other it is

possible to disregard the function of the nephritic kidney if the sick person is in good condition and the ureteral catheterization shows that the surgical kidney is doing little or no work. We are inclined to believe that it is always safe in such a case to do nephrectomy if the surgical kidney secretes no dye, even if there is urea. In all patients where there is general evidence of renal insufficiency and where the ureteral catheterization shows that the two kidneys are about equally secreting, it is a dangerous thing to remove one of the kidneys. We are inclined to feel that it would be a dangerous thing under such circumstances to remove one of the kidneys if indigo-carmin is barely excreted at all and if phenolsulphonephthalein is excreted as low as 5 per cent. for the hour. Some patients would undoubtedly survive, but there is a danger in this class of work of complete renal inefficiency. It is not safe or proper to decide as to the removability of a kidney on the basis of the output of indigo-carmin or phenolsulphonephthalein or even urea in those conditions where the disease itself does not indicate that it should be removed; we refer to tumor, tuberculosis, and so forth. We should remember that kidneys greatly depressed in function when freed of the disease will resume normal function or at least some degree of function. In a number of specimens where there has been no function worth speaking of, and in infected stone kidneys, especially those associated with obstructions, we have observed that the gross and microscopical appearance of the kidney is not greatly altered. In other words, the diseased process has temporarily caused a cessation of the function of the kidney. While in general we have found that the variations in normal cases are from ten to fifteen per cent. in some cases we have found them greater than this in the hour's output between the two kidneys. Very great variations are noted in short intervals.

Examples.—We append a few examples of different condition:

Normal kidneys, healthy people.

Mrs. S. D., age 55 years, June 14, 1911.

After catheterizing kidneys, given water and one c. c. of phenolsulphonephthalein. Collection for one hour.

RIGHT KIDNEY.	LEFT KIDNEY.
55 c. c.	57 c. c.
Urea .165 gram	Urea .228 gram
Phenol. 26.5 per cent.	Phenol. .19 per cent.

Mrs. C., age 43 years, January 31, 1911.

Patient had chronic urethritis, apparently normal kidneys. Collection for forty-five minutes.

RIGHT KIDNEY.	LEFT KIDNEY.
33 c. c.	42.5 c. c.
Urea .185 gram	Urea .172 gram
Phenol. 3.98 per cent.	Phenol. 5.3 per cent.

Mrs. H., age 21 years, November 2, 1911.

Normal woman. At the beginning of examination one c. c. of phenolsulphonephthalein and two bottles of Apollinaris water given. Note the polyuria, also note greater constancy of the phenolsulphonephthalein. The urea is increased by the polyuria, but not equally on the two sides.

First half hour:

RIGHT SIDE.	LEFT SIDE.
50 c. c.	45 c. c.
Urea .2 gram	Urea .18 gram
Phenol. .6 per cent.	Phenol. 5.5 per cent.

Second half hour:

RIGHT SIDE.	LEFT SIDE.
200 c. c.	200 c. c.
Urea .4 gram	Urea .2 gram
Phenol. 15 per cent.	Phenol. 14 per cent.

Miss E. C., age 19 years, March 2, 1911.

Normal kidneys. One c. c. phenolsulphonephthalein. Collection for an hour and forty minutes.

RIGHT SIDE.	LEFT SIDE.
25 c. c.	24 c. c.
Urea .2 gram	Urea .192 gram
Phenol. 22 per cent.	Phenol. 24 per cent.

Mrs. C., age 47 years, December 8, 1910.

Normal kidneys. One c. c. phenolsulphonephthalein. Abundant Apollinaris water. Kidneys catheterized 30 minutes later. Note the polyuria effects on water and urea.

In first 30 minutes both kidneys secreted 15 c. c. of urine containing 6 per cent. phenolsulphonephthalein.

First 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 3 c. c.	Amount 5 c. c.
Urea .05 gram	Urea .085 gram
Phenol. 1.8 per cent.	Phenol. 2.5 per cent.
Δ 1.79° C.	Δ 1.45° C.

Second 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 16 c. c.	Amount 15 c. c.
Urea .128 gram	Urea .120 gram
Phenol. 5.3 per cent.	Phenol. 5 per cent.
Δ .76° C.	Δ .60° C.

Third 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 50 c. c.	Amount 55 c. c.
Urea .150 gram	Urea .165 gram
Phenol. 4 per cent.	Phenol. 4.4 per cent.
Δ .24° C.	Δ .20° C.

Diseased kidney on one side, healthy kidney on the other.

Mrs. R. L. W., age 39 years, October 23, 1911.

This patient has no infection, but periodically casts off the mucous membrane of the pelvis of the right kidney. The examination was made a few days after this occurrence. Her total phenolsulphonephthalein output for two hours was 48 per cent. Collection made for thirty minutes.

RIGHT SIDE.	LEFT SIDE.
Amount 13 c. c.	Amount 9 c. c.
Urea .0845 gram	Urea .207 gram
Phenol. none	Phenol. 4.95 per cent.

Miss F., age 28 years, April 22, 1911.

Tuberculosis of the right kidney, very extensive. Six milligrams of phenolsulphonephthalein given. Collection for thirty minutes.

RIGHT SIDE.	LEFT SIDE.
Amount 50 c. c. urine	Amount 100 c. c. urine
No phenolsulphonephthalein	Phenol. 17 per cent.
No urea	Urea not taken

Mrs. J. E. Y., March 31, 1909.

Normal left kidney; tuberculosis, moderate, right kidney. Collection for 5 hours. Impossible to produce polyuria. Twenty c. c. indigo-carmin given, and 2 mg. of phloridzin at beginning of test.

RIGHT SIDE.	LEFT SIDE.
Amount 68 c. c.	Amount 48.5 c. c.
Urea .738 gram	Urea 1.063 grams
Sugar .45 gram	Sugar 1 gram.
Indigo-carmin 6 per cent.	Indigo-carmin 12 per cent.

Mrs. J. T. C., May 2, 1909.

Tuberculosis of the left kidney and normal right kidney.

First hour:

RIGHT SIDE.	LEFT SIDE.
Amount 16 c. c.	Amount 4 c. c.
Urea .384 gram	Urea .076 gram

Second hour:

RIGHT SIDE.	LEFT SIDE.
Amount 20 c. c.	Amount 9 c. c.
Urea .360 gram	Urea .160 gram

Patient was given Apollinaris water and 4 c. c. of indigo-carmin at beginning of test. Carmin appeared abundantly from the right side in 15 minutes; only traces appeared on the left side.

Mrs. S., March 27, 1911.

Infected hydonephrotic kidney right, normal kidney left. One c. c. phenolsulphonephthalein given after abundant water. Collection for 45 minutes. In this case a tremendous polyuria was produced, notably on the sound side.

RIGHT SIDE.	LEFT SIDE.
Amount 140 c. c.	Amount 300 c. c.
Urea .28 gram	Urea .60 gram
Phenol. 12 per cent.	Phenol. 31 per cent.

Mrs. A., February 27, 1911.

Infected right kidney with stone in the ureter. The left kidney normal. A

pyonephrosis of 150 c. c. present on the right side. Both kidneys catheterized and collection carried on for 7 hours. At the beginning of the test one c. c. of phenolsulphonephthalein given and 2 mg. of phloridzin. The phenolsulphonephthalein appeared in 5 minutes on the left side, not at all on the right. Sugar appeared in 15 minutes from the left side, not at all from the right.

RIGHT SIDE.	LEFT SIDE.
Amount 190 c. c.	Amount 298 c. c.
Urea .095 gram	Urea 1.8 grams
Sodium chlorid 1.044 grams	Sodium chlorid 2.165 grams
Δ .40° C.	Δ .95° C.
Phenol. none	Phenol. 38 per cent.

Nephrectomy was done in this case because of the infection. The kidney showed remarkable amount of functional parenchyma. Note the valuelessness of the freezing point and sodium chlorid findings.

Mrs. S., January 19, 1912.

The condition was a large stone in the right kidney. The urine was sterile and the stone gave no symptoms. Note the slight interference with function. Collection made for one hour.

RIGHT SIDE.	LEFT SIDE.
Amount 113 c. c.	Amount 148 c. c.
Urea .312 gram	Urea 3.9 grams
Phenol. 12 per cent.	Phenol. 14 per cent.

Mrs. A., February 22, 1911.

Very large stone in right kidney. Left kidney normal. No infection. One c. c. phenolsulphonephthalein and 2 mg. of phloridzin given at beginning of test. Collection for an hour.

RIGHT SIDE.	LEFT SIDE.
Amount 17 c. c.	Amount 37 c. c.
Urea .102 gram	Urea .296 gram
Sugar .25 per cent.	Sugar 1 per cent.
Phenol. none	Phenol. 14 per cent.

Bilateral kidney disease.

Mrs. S., March 20, 1911.

Interstitial nephritis, bilateral. One c. c. phenolsulphonephthalein given. Collection for 45 minutes.

First 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 11 c. c.	Amount 10 c. c.
Urea .077 gram	Urea .090 gram
Phenol. .8 per cent.	Phenol. .7 per cent.
Δ .92° C.	Δ .96° C.

Second 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 15 c.c.	Amount 14 c. c.
Urea .090 gram	Urea .098 gram
Phenol. 5.4 per cent.	Phenol. 7 per cent.
Δ .93° C.	Δ .96° C.

Third 15 minutes:

RIGHT SIDE.	LEFT SIDE.
Amount 62 c. c.	Amount 52 c. c.
Urea .124 gram	Urea .3 gram
Phenol. 8.68 per cent.	Phenol. 6.24 per cent.
Δ .31° C.	Δ .30° C.

Mrs. S., October 27, 1911.

Bilateral infected hydronephrosis. Patient given 1 c. c. phenolsulphonephthalein. Collection made for an hour. Polyuria had been produced with Apollinaris water.

RIGHT SIDE.	LEFT SIDE.
Amount 130 c. c.	Amount 173 c. c.
Urea .650 gram	Urea .519 gram
Phenol. 6.5 per cent.	Phenol. 11.5 per cent.

Miss F. P., October 31, 1911.

Bilateral pyelitis, mild. Collection for an hour. One c. c. phenolsulphonephthalein given hypodermically.

RIGHT SIDE.	LEFT SIDE.
Amount 205 c. c.	Amount 185 c. c.
Urea .480 gram	Urea .410 gram
Phenol. 14 per cent.	Phenol. 12.5 per cent.

Mrs. J., May 24, 1911.

Bilateral stone kidneys, not infected. Six mg. of phenolsulphonephthalein given. Collection for 3 hours.

First hour:

RIGHT SIDE.	LEFT SIDE.
Amount 30 c. c.	Amount 110 c. c.
Urea .48 gram	Urea .440 gram
Phenol. 10 per cent.	Phenol. 7.5 per cent.

Second hour:

RIGHT SIDE.	LEFT SIDE.
Amount 32 c. c.	Amount 25 c. c.
Urea .544 gram	Urea .0875 gram
Phenol. 7.6 per cent.	Phenol. 3 per cent.

Third hour:

RIGHT SIDE.	LEFT SIDE.
Amount 30 c. c.	Amount 25 c. c.
Urea .4950 gram	Urea .100 gram
Phenol. 4 per cent.	Phenol. 2.5 per cent.

CHAPTER XII.

METHODS OF EMPLOYING THE X-RAY IN UROLOGICAL DIAGNOSIS.

GENERAL CONSIDERATIONS.

Importance.—The various X-ray methods of investigating the urinary tract have become indispensable to the genito-urinary surgeon. In some cases diagnosis can be made by means of the X-ray, unattainable in any other way. In other instances a tentative diagnosis is confirmed, and not infrequently when the X-ray is used habitually unexpected discoveries are made.

The X-ray is chiefly used to-day to demonstrate a stone in the bladder, prostate, ureter, or kidney; to reveal certain conditions, such as a diverticulum of the bladder, enlargement and changes in the form of the bladder, enlargement of the ureter, tuberculous kidney, hypernephroma of the kidney, as well as a hydronephrotic renal pelvis; and sometimes to determine, too, the character and extent of the surgical operation.

While the use of a radiograph is elective in some of these conditions, it may be said to be indispensable in cases of suspected stone in the upper urinary tract. Its use in all kinds of doubtful and puzzling cases has shown the existence of urinary calculi, where the symptoms have been slight and indefinite. The presence of stone in the kidney is far commoner than is generally supposed (Carman).

So important has this science of radiography become, that, whenever it is possible, the urologist should arrange for an X-ray laboratory as an adjunct to his office. The arrangement should be so satisfactory and convenient that he will use it not only in the obviously important cases, but in all kinds of doubtful conditions as well. In other words, the more the physician has his apparatus at his disposal and is able to play with it, the more substantial aid is he likely to receive from it in the end.

Although radiography is so satisfactory in many cases, it by no means excludes any other previously recognized exact methods of investigation.

For example, the history of the patient must be taken just as carefully, the urines must be separated and examined with the same degree of precision,

ureters catheterized, and the renal pelves gauged by injection, both to measure size and to test the location of pain, the wax-tip bougie must also be used for the diagnosis of stone. Only by using all the various methods of precision will the urologist justify his specialty and be able to do justice in all his cases.

Outfit Needed.—The best modern outfit is one in which a transformer is used. These are made in two types, adapted to either alternating or direct current. The transformer converts a current of low tension, such as is used in city lighting circuits, to an unidirectional current of extremely high tension suitable for this work. The newer apparatus is more expensive than the earlier form, where an induction coil was used, but by its use the time of exposure is greatly shortened, and blurring of the image from respiratory movement is obviated. The coil is rapidly passing out of use, except for fluoroscopic work, and is, therefore, not considered here.

The initial cost of a good outfit is about fifteen hundred dollars; there are several excellent American machines on the market.

The characteristic of a good tube is the ability to take a heavy charge without injuring its target, while at the same time it holds a uniform vacuum during a fairly long exposure.

Heat tends to melt the anode and to lower the vacuum in the tube; to overcome this difficulty some tubes are made with a water-cooling device back of the target. A compression diaphragm is invaluable in abdominal work, crowding the tissues together and fixing the parts. This brings the tube closer to the plate and so gives better definition while it shortens the exposure. This is especially useful in kidney work.

An intensifying screen made of calcium tungstate is of service in giving quick exposures. It is placed under the photographic plate in contact with the film, which is reversed in this instance so that the rays first traverse the glass.

The photographic plates vary in size from 8 by 10 inches to 14 by 17 inches; they are the usual silver bromid gelatin emulsion heavily coated. The best results have been secured with imported English plates.

The development of the plate in the dark room is of great importance, for often a good exposure is sacrificed by poor treatment at this stage. As the rays act through the emulsion, it is a good rule to subject it to a prolonged development with a dilute developer. If the exposure is just right the dark-room treatment is simplified. The several (four) factors concerned in the exposure, namely, distance, thickness of tissues, penetration of tube, and quantity of current, all regulate the length of the exposure. These can be combined in a simple formula which is an aid in determining it.

Preparation of the Patient.—The preparation of the patient consists in thor-

oughly cleaning out the colon by means of a vegetable purge and regulating the diet. If this is extended over a period of from three to five days better and more uniform results are obtained. When the examination extends into the pelvis the bladder should be emptied just before taking the picture; also in patients inclined to constipation a high enema is beneficial.

The purgation is effected by giving vegetable cathartic pills at bedtime, followed the next morning by eight grains of phenolphthalein. Repeat this every other day for a week (Quinby). The patient should take liquid for

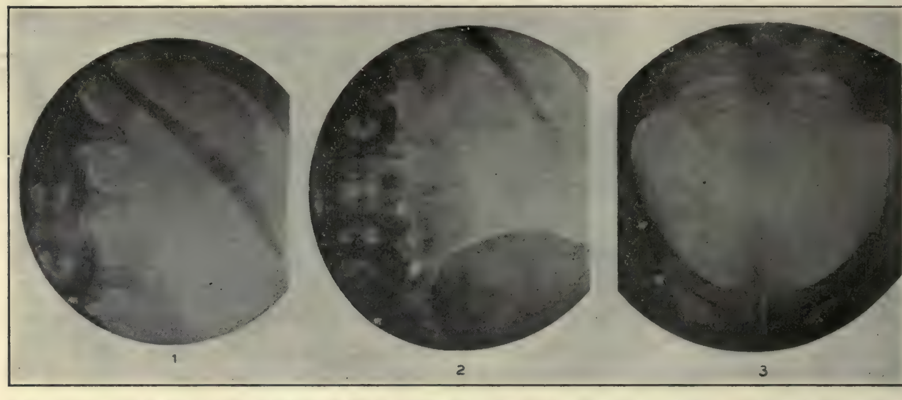


FIG. 159.—NECESSARY VIEWS FOR COMPLETE X-RAY EXAMINATION OF THE URINARY TRACT (after Haenisch). 1. Immediate kidney region. Note normal kidney outline, distinct psoas shadow, transverse processes of vertebræ and 11th and 12th rib. 2. Ureteral area from second lumbar vertebræ to crest of ilium. 3. The lower ureteral and bladder area.

two or three days and do with as little food as possible for twenty-four hours prior to the X-ray examination.

In taking the picture, the vertebral column should lie as close as possible to the plate; this is done by flexing the knees and raising the shoulders, thus getting rid of the natural lordosis.

Methods of Examination.—Every examination should include the whole urinary tract. If but one side is ordered for the radiographic examination, then the responsibility for failure in cases of transferred pain and other cases of unsuspected bilateral calculi rests not with the radiographer, but with the physician sending the patient. As Carman cleverly says: "This is somewhat comparable to an oculist examining only one eye in a case of defective vision."

THREE-PLATE METHOD.—There are two good ways of examining; the one which we employ may be called the three-plate method. Here one takes a local

view of each kidney, using the compression diaphragm, and then a large (11 x 14-in.) plate of the rest of the urinary tract, centering the tube above the umbilicus. A larger compression diaphragm which does not touch the body may be used with the large plate. This assists in excluding the secondary rays, and if properly placed does not contract the field.

Five-plate Method.—Another method (Haenisch) is that of taking five plates, one of each renal region, one of each lumbar region, and one of the pelvis (Fig. 159). Cole defines the field of these local plates as follows:

"Renal: The radiograph of the kidney region should show the eleventh and twelfth ribs, and the first, second, and third vertebræ (lumbar).

"Ureteral: The ureteral radiographs extend from the third lumbar vertebræ to the brim of the pelvis.

"Bladder: The radiograph of the pelvis includes the pubis below and extends up as far as possible."

Every plate which includes both sides should be marked R and L, in order to avoid serious mistakes. Fenwick tells of a case where the wrong kidney was exposed owing to a neglect of this simple precaution.

Doubtful conditions ought to be radiographed twice. This will do away with any misinterpretation arising from faulty plates or fecal concretions.

It is a good plan, on finding a stone, say in the kidney, to make another plate one or two days later to verify the first.

Stereoscopic Pictures.—Stereoscopic pictures are of the utmost value, particularly in calculi, serving to throw the stone out in full relief in front of the posterior plane of the tissues of the body. The stereoscopic picture is also valuable when the pelvis of the kidney and the lumen of the ureter are injected with collargol, showing size, form, and dimensions which cannot be seen in the single plate.

The stereoscopic method is also of use when an opaque catheter is inserted and when there is a stone in the ureter or bladder. The bougie, under these circumstances, furnishes a ready landmark by which the position of the stone is easily gauged.

Aids to the X-ray.—Adjuvant to the use of the X-ray is the employment of bougies or catheters charged with a metallic preparation, which cast a shadow and serve to mark out the urinary tract, distinguishing a stone in a ureter, for example, from a stone outside of it (a phlebolith).

By injecting collargol (10 per cent. in water) the urinary tract can be filled with a solution which is opaque to the rays, and furnishes a silhouette of the renal pelvis, and the ureter and the bladder. This is most valuable in

dilatation of the renal pelvis and ureter and in distention of the pelvis, as shown many times by Braasch in hypernephroma.

Since the introduction into urological diagnosis by Voelcker, Lichtenberg and others of the Heidelberg Surgical Clinic and its popularization by Dr. Braasch in this country, the radiographic examination of the ureter, pelvis and calices by means of the injection of opaque substances, has become very popular and much used.

It is a method which appeals to the eye, gives a permanent record, and aids the diagnosis materially in many cases. In his original communication, Voelcker advised using a 2 per cent. aqueous solution of collargol. Braasch advises using a 10 per cent. solution. We have used almost every strength between these two and are inclined to feel that the best results are obtainable only with the stronger solutions.

Doctors Uhle, Pfahler, MacKinney and Miller of Philadelphia (*Ann. of Surg.,* 1910, li, 546) employed a number of silver salts for this same purpose and finally settled on colloidal silver oxid, sold under the trade name of cargentos. They use a strength of 50 per cent. in their injections.

Dr. Robert M. Lewis of our clinic has been experimenting during the past year most satisfactorily with a 5 per cent. emulsion of silver iodid suspended in mucilage of quince seed (*Surg. Gyn. and Obst.,* 1913, xvi, 707). This preparation gives a shadow quite as intense as a 10 per cent. collargol solution, and is apparently less irritating to the kidney. The suspension will stand for days without precipitating and passes out of the kidney pelvis and ureters completely in a few hours, as he has shown by X-ray pictures taken to demonstrate this point.

The silver iodid has the two properties of being less irritating and less likely to be followed by severe renal colic when compared with collargol.

Various methods have been employed for introducing the silver salt into the renal pelvis, some of them making use of gravity. It has been claimed by some observers that a small catheter which allows a gradual reflux is of advantage. Our own method has been to catheterize the patient on the X-ray table, having the tube set and focussed and everything ready, and then to inject, by means of a syringe, into the pelvis. The syringe method is the same as we employ for irrigating the pelvis or for measuring hydronephrosis, and is shown in Figure 268 (Chap. XVII).

While this method affords striking aid in diagnosis it should be employed with care and, in our opinion, only where necessary. In the urological clinic at the Johns Hopkins Hospital, there have been, according to personal com-

munications from Dr. John Geraghty, two cases in which patients have developed a hemorrhagic nephritis from the injection. Jervell (*Arch. générales de chir.,* 1912, vi, 806) has reported a case of partial gangrene of the kidney following collargol injection. Prof. Rovsing of Copenhagen personally communicated somewhat similar results. In many of the patients a severe renal colic follows which may last for 24 hours or longer. We do not consider that these facts contraindicate the method, which has been so frequently and so successfully employed by Braasch and others, but we do consider that they are sign-pointers indicating that extreme care should be exercised in giving the injection and only such patients injected as need clearing up from the diagnostic standpoint.

An explanation of Dr. Geraghty's case is perhaps afforded by a report of Dr. Buerger (*Amer. J. Urol.,* 1912, viii, 166) which mentions finding collargol deep in the renal parenchyma two weeks after the injection. In this case the injection had revealed a ureteral stricture, which operation showed not suitable for plastic repair and necessitating a nephrectomy.

F. Zachrissohns (*Nord. med. Ark.,* 1911, xi, No. 27, 1-13; ref. *Folia Urologica,* 1913, vii, 535) reports the collargol injection of the left kidney of a servant girl. In addition to showing the outline of the pelvis and calices, the skiagram clearly showed penetration far up into the tubules. This patient had a bad hydronephrotic kidney on the other side. There were colicky pains for five days following the injection, with fever for fourteen days and one year later there were still casts in the urine.

A splendid review of the method and results of this procedure can be found in the recently published work of Legueu, Papin and Maingot ("Exploration radiographique de l'appareil urinaire," Paris, 1913).

Criteria of a Good Picture.—The characteristics of a good plate are expressed by Cole, who says:

"One is not justified in making a negative diagnosis of renal or ureteral calculus unless a plate of the renal region shows the following detail: (1) The spine and transverse processes should show distinctly all the way to the tips; (2) the outer border of the psoas muscle must show. In some very flabby, fat patients it may not show as distinctly as the kidneys; (3) the eleventh and twelfth ribs should show distinctly, and in many cases the bony details may be distinctly seen; (4) in about 75 per cent. of the cases the kidney may be seen more or less distinctly, and, if special care in technique is used, it may show in nearly every case; (5) the liver is frequently seen, and at times it interferes with showing the convex surface of the upper pole of the right kidney."

R. D. Carman very clearly says of a good radiograph: "Rather, I think, should it be defined as one which shows the outline of the kidney."

It is a good rule in all cases to take a verifying plate a day or so later and before operation. By doing this other small stones may be found, and the surgeon will be informed of any change in the position of the stone.

CASES FOR USE OF X-RAY.

The kind of cases in which the X-ray is useful are:

KIDNEY: Stone; dilated renal pelvis; irregular renal pelvis (hypernephroma); tuberculous deposits.

URETER: Stone; dilatation; double ureter; kink in ureter.

BLADDER: Stone or other foreign body; distention; diverticulum.

THE KIDNEYS.

Stone in the Kidney.—If we must select a single field in which the use of the X-ray affords the most gratifying results, we must unquestionably name stone in the upper urinary tract, in the ureter, and in the kidney.

While the wax-tipped bougie in the hands of a few examiners has given excellent results, it may be said without fear of contradiction that, until the advent of radiographic methods, the profession at large had no certain, direct means of detecting stone.

By this procedure the diagnosis can be made certain, and the best observers do not miss over two per cent. of the cases. G. F. Haenisch has only missed 3 in 300 cases. A safer estimate more in accord with the average facts in common practice is perhaps an error of 5 per cent.

Before taking the radiograph, the bowels must be emptied as described on page 348. Most errors and disappointments arise from insufficient preparation. Fenwick finds that renal stones practically always lie inside a line falling vertically from the last rib to the middle of the crest of the ilium (see Fig. 160).

We have taken a radiogram of a normal subject, and upon it plotted out the findings in 100 cases of stone in the kidney and its pelvis, representing each stone by a dot at its center (Fig. 161). A cluster of stones taken is also represented by its center. In this way all the stones in this group were found to lie in the position indicated in the diagram, extending from a point high up between the eleventh and twelfth ribs down to a point within an inch of the

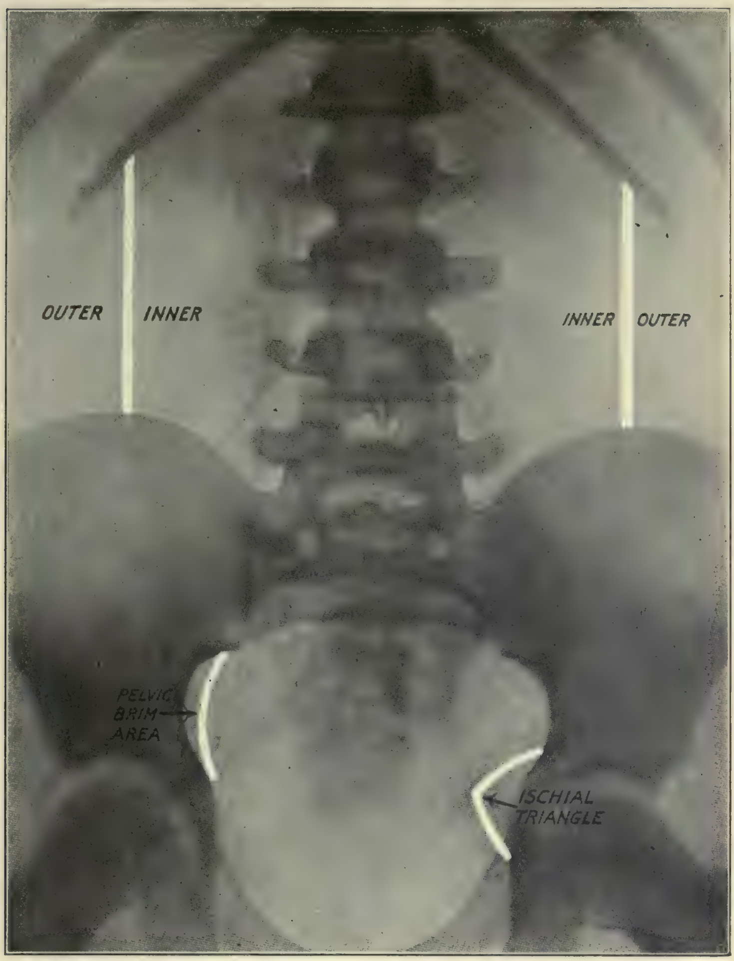


FIG. 160.—RADIOGRAPHIC DIAGRAM TO SHOW SITE OF RENAL AND URETERAL STONES. The white lines run vertically from the middle of crest of ilium up to rib. Area marked "inner" includes almost all stones. Shadows in area marked "outer," probably not stone. Area marked "pelvic brim," common site of calcified lymph glands. Area marked "ischial triangle" frequently contains phlebolith. (From Hurry Fenwick.)

crest of the ilium. In one case a displaced kidney lay below the crest (Fenwick). The figure thus formed by these stones presents a fairly definite oval shape, and serves as a good guide in estimating just where a stone is lodged.

A single stone is apt to be oval; if it is large, it may present a teat-like

process projecting downward from its inner margin, pointing into the ureter. A stone of this sort held in the renal pelvis, associated with peripheral shadows of smaller stones, often indicates the presence of a large branched calculus.

FIG. 161.—RADIOGRAPHIC DIAGRAM SHOWING POSITION OF KIDNEY STONE IN 100 CASES. Each dot represents the center of a single stone or of a cluster of stones. Note high position, especially on left side. Note low position in one case of displaced kidney. Taken as a whole, the dots fairly outline the kidneys.

A calcified tip to a transverse process may give a shadow like a stone in the renal pelvis. This difficulty may be overcome by observing that other tips are calcified on the same or on the other side, as well as by taking another picture with the light placed more obliquely. In Figure 162 is shown the lo-

cation met with in 100 cases of ureteral stones. Compare this with Figure 163 showing the location of 50 phleboliths.

Sometimes the twelfth rib obscures a stone, as shown in Figure 164. In

Fig. 162.—Composite Photograph of 100 Ureteral Stone Cases. Black dots represent the position of ureteral stones.

this case the difficulty was obviated by pulling up the margin of the ribs (see Fig. 165), and taking another picture when the stone was found standing alone.

As Fenwick has pointed out, what appears to be a single stone may be a

group or patch of stones. In large branching stones the connecting branches may disappear, so that the picture shows only the mass in the renal pelvis and the cusps which may be arranged on a curved line. A lot of stones arranged

FIG. 163.—COMPOSITE PHOTOGRAPH OF A NUMBER OF PHLEBOLITH CASES. Black dots represent the location of 50 phleboliths.

more or less vertically at intervals represent stones in separate calices, "cortical stones situated in the cortical substance of the kidney."

Stones have been demonstrated several times in a horseshoe kidney. "In general the shadow of a stone low down lying upon the vertical column shows the presence of a horseshoe kidney" (Kienlock).

Other important rules laid down by Fenwick are the following:

"A sharply defined dense shadow in the renal area of a young adult who suffers from symptoms of stone (the urine being oxalescent and aseptic) indicates an oxalate of lime calculus.

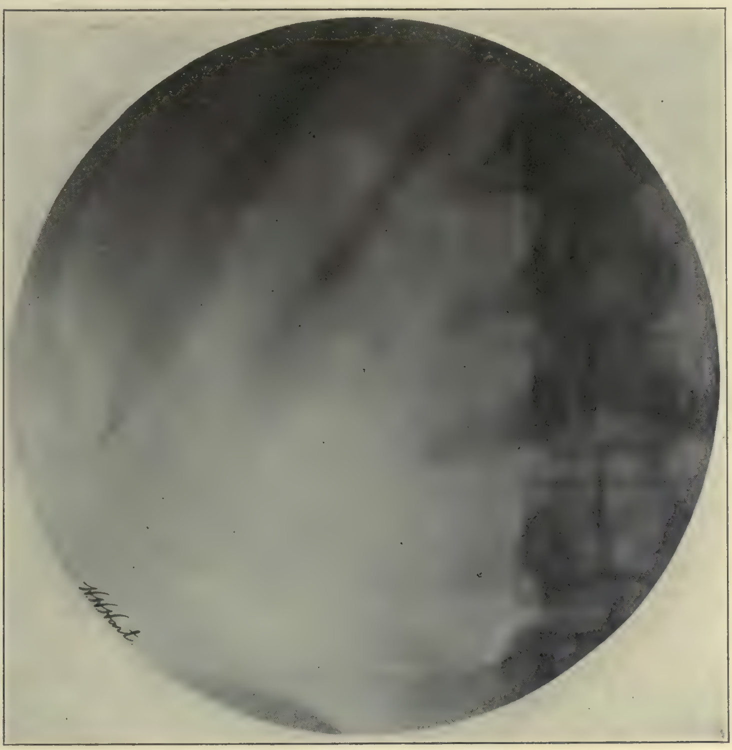


FIG. 164.—RADIOGRAM OF LEFT KIDNEY SHOWING SMALL STONE IMMEDIATELY IN FRONT OF TWELFTH RIB. (Case of M. L. B., Nov. 20, 1911.)

"Discrete shadows arranged along the mid-vertical usually denote stones in a dilated calyx, or, in other words, cortical stones which are situated in the cortical substance of the kidney as distinct from those in the pelvis of the organ.

"Widely isolated cortex stone shadows do not necessarily denote widely isolated stones.

"Small discrete cortical stone shadows denote a kidney distended by back

pressure. They do not mean widely isolated stones, but stones separated by fluid, either urine or puriform urine (hydronephrosis or pyonephrosis).

"When the shadows are multiple and arranged irregularly along the spinal column, or along the sharp brim of the true pelvis, they can safely be regarded as cast by calcareous glands."

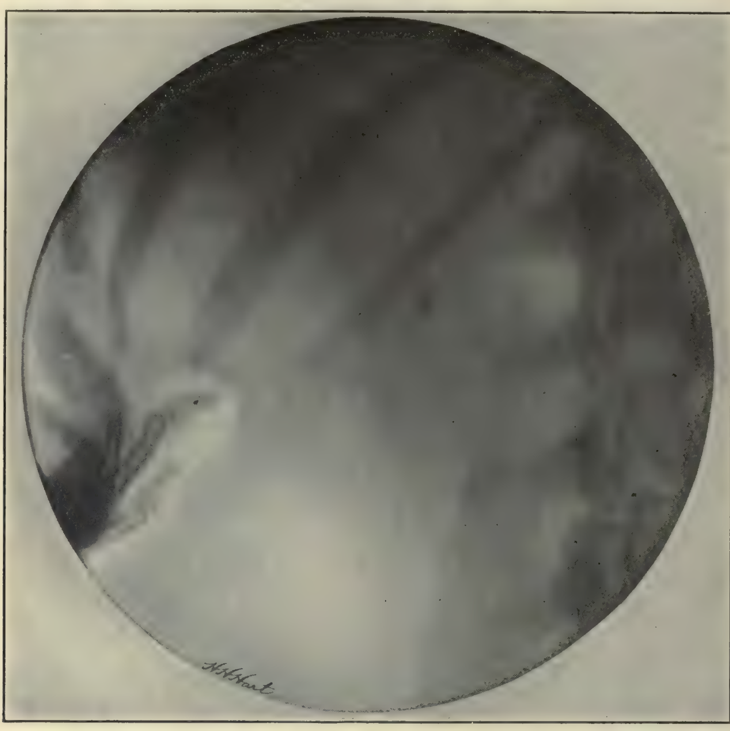


FIG. 165.—RADIOGRAM OF SAME KIDNEY SHOWN IN LAST FIGURE, WITH THE RIBS FORCEFULLY PULLED UP BY THE HAND.

A good radiogram often gives the surgeon the number as well as the size and the location of the calculi. In this way it may exercise a strong determining influence over the steps of the surgical operation. If a solitary stone is seen in the renal pelvis the surgeon will naturally avoid doing an exploratory operation on the renal tissue and will confine his attention to the pelvis of the kidney and extract the stone in that way when it is possible. If two stones are seen widely separated, he will then look for each of them and not overlook one, as frequently happened in former days. If a solitary stone is

discovered in the upper pole of the kidney, as in one of our recent cases (Fig. 166), he will make an incision at that point and deliver the stone without doing further damage.

In such a condition a most conservative operation can be done for a stone's delivery with a resultant minimal damage to the substance of the kidney and minimal hemorrhage, by opening the fatty capsule, freeing only the upper pole of the kidney, and gently and carefully tilting this down and out of the upper angle of the wound until about one-third of the kidney is exposed to view. Then a minute incision is made through the capsula propria of the kidney and a fine blunt needle pushed inward in the direction where the stone is believed to lie. As soon as the stone is detected, the opening in the fibrous capsule is enlarged to 1 cm., or more if necessary, and a blunt instrument introduced, and the kidney is deliberately and gently torn open in a straight line until the stone is exposed and extracted from its calyx by its smallest diameter with a small stone forceps. Such a little wound in the capsule is then easily closed with two or three interrupted fine catgut sutures.

Fig. 166.—Radiogram Showing Stone in Upper Calyx of Right Kidney. Note outline of kidney and relation of stone to short twelfth rib. (Case of Mrs. T., Nov. 17, 1911.)

This same principle is applicable to a solitary stone in any other part of the kidney. The lower pole can be tilted up and similarly exposed and in-

cised, or the waist or middle part of the kidney can be brought out and treated in like manner.

Fenwick further adds these rules:

"A triangular-shaped shadow in the renal region with the nose pointing downward and with phosphatic urine renders early operative removal of a pelvic stone necessary before serious damage to the kidney ensues.

"A large renal shadow with rays or branches indicating a dendritic stone with fetid pyuria generally demands nephrectomy."

Conditions Other than Calculus.—We are able with the X-ray to demonstrate a DISPLACED KIDNEY, whether the displacement is acquired or congenital. By this means also a large kidney has been shown on one side, while the absence of a kidney has been demonstrated on the opposite side. This demonstration is easily made also in cases of nephrectomy some months after the operation. A compensatory enlargement of the sound kidney can also be shown where there is extensive disease of one side of long standing.

Haenisch speaks of several cases in which a HORSESHOE KIDNEY has been shown by the stones present in the pelvis. Here a collargol injection ought to give a remarkable picture of a displaced, more or less saddle-bagged renal pelvis straddling the vertebræ.

In practically all cases in which it is desirable to make an X-ray examination of the kidney apart from the presence of stone, the diagnosis is greatly assisted by the use of collargol injected into the pelvis of the kidney, which is then radiographed. In this way hydronephrosis and pyonephrosis are plainly demonstrated, and alterations of the pelvis are shown, justifying the diagnosis of a tumor.

HYPERNEPHROMATA.—Voelcker of Heidelberg has made this subject largely his own by a series of exceedingly careful studies. W. F. Braasch of this country has discovered an irregular form of the renal pelvis quite constantly associated with hypernephroma (*Ann. of Surg.,* April, 1910). He says that of 30 hypernephromata removed in the clinic at St. Mary's Hospital nearly all show a deformity of the renal pelvis, and this deformity has been demonstrated in the collargol plates. There is a dilatation due to retraction in the walls of the pelvis by the surrounding tumor, making the pelvis abnormally broad at the uretero-pelvic juncture, while the infundibuli are short and broad. This pelvic dilatation may be confined to a single calyx, which is then drawn out long. Another form of dilatation is due to a secondary degeneration of the surrounding tumor, with sacculation of the pelvic walls. When the new growth encroaches on the lumen of the pelvis, then this is diminished in size and often small and irregular at the end of the ureter.

In HYDRONEPHROSIS, when the pelvis of the kidney is injected with collargol through the renal catheter by gravity alone, stopping short of the induction of pain, the collargol injection, when radiographed, shows the massive and large pelvis with branches extending outward toward the cortex, the calices being larger or smaller, according to the extent of their involvement (Fig. 167).

FIG. 167.—RADIOGRAM OF HYDRONEPHROTIC LEFT KIDNEY. 150 c. c. capacity, distended with 10 per cent. collargol solution. Note immense size of pelvis and calices; note how calices all have a bulbous instead of a pointed outline. (Case of Mrs. E. C. S., Dec. 8, 1911.)

Not infrequently this enlargement involves only one portion of the kidney, when the enlargement is asymmetrical.

Braasch has some excellent pictures of these conditions in his article in the *Annals of Surgery* (1910, li, 534). There is, however, a difference between our observations and those of Braasch in that we rarely find a normal pelvis exceeding 12 c. c., while the great majority of our renal pelves range from 7 to 8 c. c. in capacity; and Braasch makes allowance for normal

renal pelves holding 18 or even 25 c. c. Further careful observations will correct the error here wherever it may lie.

Renal Tuberculosis.—Some valuable observations have been made upon the use of the X-ray in determining the presence of a renal tuberculosis. The most important practical communication upon this head is a paper by von Lichtenberg and Dietlin (*Mitt. a. den Grenz. der Med. u. Chir.*, 1911, xxiii, Bd. 5, 739), who used the collargol method of injection and so brought into sharp relief the altered or disorganized renal calices.

Taken with other methods of examination already in use, the X-ray pictures afford the most striking and satisfactory confirmatory evidence of tuberculosis. They also afford sometimes the evidence of a large tuberculous ureter, in this way assisting the surgeon in demonstrating the extent of the operation.

On the one side the changes are due to the destruction of the papillæ and the formation of open cavities, while on the other there is a disappearance of portions of the normal communications between pelvis and calyx caused by the filling up of the broken-down portions with cheesy matter and detritus. Everywhere that the destruction of the kidney is progressive, the contours of the normal renal cavities are indistinct and more or less angular. The mixture of the collargol with the tuberculous pus causes formations of a shadow varying in intensity with the amount of collargol. The picture obtained in this way shows a decided difference from hydronephrosis and pyonephrosis.

An old inflamed kidney often casts shadows on account of the accumulated fibrous tissue; this is apt to be marked in the peripheral portion where the rays traverse more of the inflammatory structures.

THE URETER.

Ureteral Calculus.—Under ordinary conditions the normal ureter does not appear in the radiogram. It only does so when it contains a stone which serves to mark its position, and under such circumstances the X-ray reaches perhaps its highest value. Leonard estimates that somewhat over half the urinary stones found are discovered in the ureter, and makes use of this means also of determining whether the stone is moving down the urinary tract or not. Haenisch estimates 37 per cent. of ureteral stones.

In Figure 168 we have plotted the locations of stones in 28 ureteral cases.

By using a ureteral catheter made opaque by metallic salt, or injected with bismuth, the whole ureteral tract can be followed and a differentiation easily made between ureteral stones, phleboliths, and calcified glands, including also

foreign bodies in the appendix. The little round phleboliths, 3 to 5 mm. in diameter, are quite characteristic and differ markedly in appearance from stones in the ureter; they are frequently multiple, sometimes scattered, and

Fig. 168.—Diagram Showing Position of Stones in 28 Cases Where They Were Located in the Ureters. Each dot represents a center of stone.

laterally placed, their position thus demonstrating that they are extra-ureteral (Fig. 168).

Fenwick has marked out a small triangular area within the pelvis, which he calls the ischial triangle, a frequent site for phlebolith shadows (Fig. 170)

FIG. 169.—SHADOWS CAST BY VERMIFORM CONCRETION AND BY PHLEBOLITH. Upper shadow (black arrowed) upon the iliac crest is cast by a fecal concretion in appendix. Small, round shadow in pelvic area is a phlebolith. (After Hurry Fenwick.)

while the pelvic brim area a little further back in the true pelvis, taking in the inner crescentic curve of the ilium, is the location where the calcified glands are oftenest found. He further says that, while the phlebolith shadow may underline the pelvic portion of the ureter, this rarely happens if the light

is placed centrally. Whenever the stone or phlebolith coincides with the line shadow of the bougie, a stereoscopic picture should be taken.

He lays down the following rules:

"Do not casually diagnose a round, sharply defined bright spot in the negative of a bony pelvis area to be a ureteric stone, even though it lie in the direct

FIG. 170.—RADIOGRAM SHOWING 5 PHLEBOLITHS IN REGION OF RIGHT ISCHIAL SPINE. Note shadow at the crest of left ilium. This is due to a platinum tube containing 30 mg. of radium, which patient had swallowed by accident and which is now present in the sigmoid flexure.

line of the ureter. Insist upon a stereoscopic radiogram. If still doubtful, pass a radiographic ureteric bougie (one impervious to X-ray), and let the patient be stereoscopically rayed again with the bougie *in situ.*

"Suspect multiple sharply defined spots in the negative of a bony pelvis area, especially if they are grouped around the shadow of the ischial spine, to be phlebolith shadows.

"A shadow inside the mid-vertical and in the lower half of the loin space,

the kidney being immobile and not displaced, is probably cast by a ureteric stone.

"A small shadow in the bony pelvis area is suggestive of stone in the lower ureter if it is in the line of the ureter, and is oval or more or less elongated, and if its axis is directed more or less downward toward the bladder, and if the clinical history of ureteric stone is in accordance."

A vermiform concretion occasionally casts a sharp shadow, as in Figure 169 (from Fenwick). This has been noted a number of times. The direction

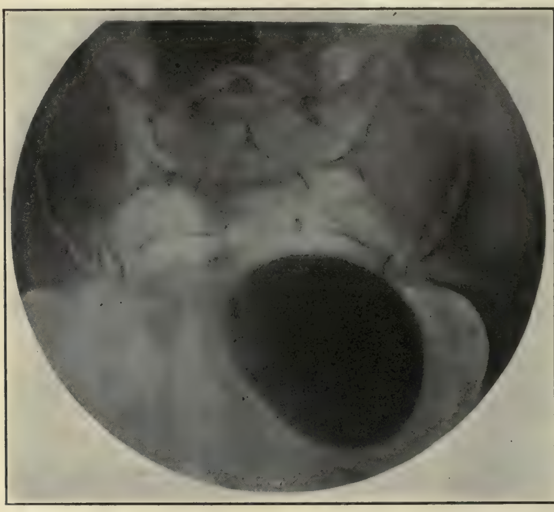


Fig. 171.—Radiogram Showing Large Vesical Stone Which Could Not be Demonstrated by Cystoscope. It was in a diverticulum. (After Haenisch.)

of the axis and the position of the calculus show that it is not ureteral. Any doubt would be set at rest by using a shadowgraph bougie.

Double Ureter.—Double ureter can be found on introducing two catheters, one up through each orifice. This would be valuable in some cases of stone, or of tuberculosis, or of infection where the disease may be limited to half of the kidney. Brown, Engelbach, and Carman have demonstrated double ureters on both sides (see excellent article, *Trans. South. Surg. and Gyn. Ass.*, 1909, xxii, 248).

Dilatation.—A dilatation of the ureter due to strictures or to a stone shows admirably in the shadow picture when the ureter has been emptied first and then injected with the 10 per cent. collargol solution. Such an enlargement

of the ureter is always continued up to and associated with a dilatation of the pelvis of the kidney.

Torsion.—Voelcker and von Lichtenberg have described the torsion of the ureter due to displacement of the kidney.

THE BLADDER.

While radiographs of the bladder are not so indispensable as those of the upper urinary tract, they do often give valuable confirmatory information;

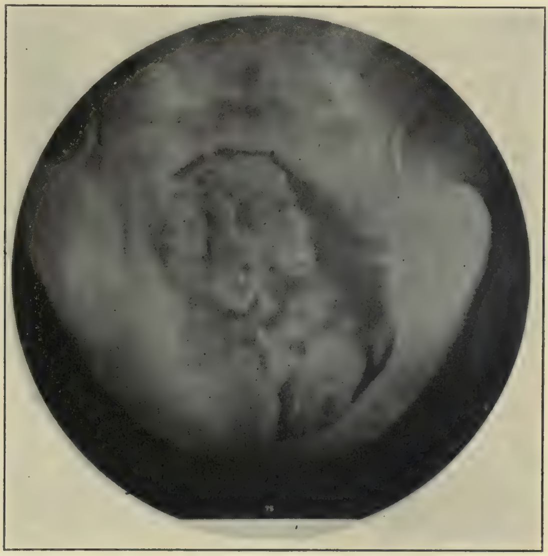


Fig. 172.—Radiogram of the Pelvis of a Patient Suffering with New Growth of the Bladder. The bladder has been treated with a 10 per cent. bismuth emulsion. (After Haenisch.)

sometimes they serve to complete a diagnosis, and, again, occasionally a diagnosis is made which has been missed by the classical methods of investigation.

As in the kidney and in the ureter, a stone is the object most easily shown. It is more difficult here on account of the position of the organ relative to the light and the plate. In order to correct this, a sitting posture has been employed.

An oval bladder stone commonly lies in a characteristic transverse position.

To overcome the shadows of the inferior muscles and to bring the plate

nearer to the object, Seiffart has inserted a narrow plate into the vagina; this has also been done with success by Cordier, of Kansas City.

If the bladder is filled with air (Wittek) or oxygen this makes a beautiful contrast with the dark shadow of the stone, throwing it into relief.

A diverticulum containing a large stone has been demonstrated by Haenisch when the opening from the bladder could not be detected cystoscopically, even after it was known to exist (Fig. 171).

The shadow picture also demonstrates the number and the size of the stones. A large median lobe of the prostate has been known to conceal a stone so that it failed to impress the plate.

Other foreign bodies are also readily seen, especially the familiar hairpin.

By distending the bladder with air, a diverticulum can be demonstrated.

The size, form, and position of the bladder are best demonstrated by injecting a 5 or 10 per cent. collargol solution, which also brings out a diverticulum.

A 10 per cent. bismuth emulsion can also be used; by this means Haenisch has shown a large bladder tumor with the bismuth crowded crescentically on the right and entering the mass in feathery projections (Fig. 172). A similar condition was found in one of our own patients, except that the mouth of the diverticulum was large enough to show that the stone was present. It could not be detected by sounding. Skiagram is shown in Figure 383.

CHAPTER XIII.

THE SYMPTOMATOLOGY OF URINARY DISORDERS.

In the separate chapters of this book we have discussed the underlying anatomy and pointed out the symptoms which arise with the various diseases. An accurate and correct diagnosis must rest on a most careful general examination accompanying a detailed and thorough urological examination. Nevertheless, a thorough consideration of the symptoms noted by the patient is a necessary and invaluable guide toward diagnosis. For this reason we embody in a short chapter some general considerations in regard to the symptoms, which should aid in the developing of careful history taking.

HEREDITY.

The question of family disease does not enter very seriously into the picture of a urological case, although such conditions as stone, prostatic hypertrophy, tuberculosis, and neoplasm tend to run in certain families.

PAST HISTORY.

The past history may be quite important. This applies not only to diseases of the genital or the urinary organs themselves, but to the entire body. The acute infectious diseases, infections of any kind, i. e., tonsillitis, boils, abscesses, may be the origin of an existing nephritis or infection of the urinary tract. A history of syphilis or of some nervous disease may at once point out the source of various dysurias.

Operations on the genital organs, especially in woman, are the frequent cause of urinary diseases and symptoms.

PRESENT ILLNESS.

In the present illness it is wise and necessary to consider the body as a whole, and not to confine one's attention to the urinary organs. We need here

merely mention the association of heart and artery disease with nephritis; of infections in other parts of the body with pyelitis or cystitis; of hysteria, and neurasthenia, with pain and discomfort in all parts of the urinary tract.

The symptoms which attract the attention of a patient and which must be sought for by the physician are both general and local.

The general ones are principally those which arise from insufficient renal function, from sepsis due to infections, and also, to some extent, the marasmus which follows malignant disease.

Renal Insufficiency.—Renal insufficiency is characterized by a great variety of symptoms. In the very early stages there may be just occasional headache, giddiness, a tired feeling, and perhaps slight gastric disturbance. Almost every function of the body may be interfered with. Witness the asthmas of renal origin, which in profound cases may be represented by the Cheyne-Stokes breathing. The nervous symptoms are most varied, all the way from mild neurasthenia to marked psychoses. Uremic convulsions, so common in nephritis, are rare in purely surgical types of kidney disease. Coma, on the other hand, is not uncommon. Various disturbances of vision due to retinitis are common. Swelling of the feet and hands and dropsy are rarely met with in the surgical affections of the urinary tract, but are common enough with the various forms of acute and chronic glomerular nephritis.

The local symptoms which attract a patient's attention are, first and foremost, pain; second, alteration in the normal or customary physiologic function; third, changes in the appearance of the urine; fourth, the development of palpable enlargements, such as arise from tumors.

For convenience sake the symptoms will be taken up as they arise from the kidney, from the ureter, from the bladder, and from the urethra.

Kidney Symptoms.—It is not uncommon in cases of greatly *enlarged kidney*, such as occur in neoplasm and hydronephrosis, for the patient to note the condition and come to the physician on account of it. In the separate chapters we have discussed the methods of differentiating kidney tumor from those due to enlargement of other organs.

The laity is also rather wide-awake in the observance of *abnormal conditions of the urine*. Turbidity, redness, foreign bodies such as gravel are all anxiously observed. A consideration of this feature of the symptomatology is given under the headings of hematuria, pyuria, pneumaturia, and the urinary examination, and need not be repeated here, except to note that the physician should always pay attention to these complaints and make careful examination to determine whether they are well founded or not.

Occasionally a patient will note the passage of abnormal quantities of

urine. Polyuria is of course always associated with excessive water drinking, but is also characteristic of certain diseases, as diabetes, diabetes insipidus, chronic interstitial nephritis, pyelonephritis, urinary retention.

Pain.—Pain in renal disease may be associated with the kidney or with the bladder. The bladder disturbance may be independent of any actual organic involvement. The explanation here offered is that the urine contains irritating substances, that it is purely a reflex phenomenon, and that there is slight but undetectable disease of the bladder. However, before taking up this question of bladder symptoms, let us investigate the question of renal and ureteral pain. That which arises from the kidney may be continuous or intermittent—a slight ache or most severe. In milder forms it is, as a rule, located in one place. In the severer, it is likely to radiate. It has long been recognized that the typical renal pain in kidney colic begins in the back and radiates down the course of the ureter, to the ovary in the female, and to the testicle in the male. In some cases, however, the radiation does not occur in this typical way, for pain may radiate to the opposite side of the body or to the chest, and sometimes down the leg. Rarely is there found an attempt to explain this pain radiation in renal colic. It is, we believe, due to the nerve distribution. The kidney, ureter, ovary, and testicle are all supplied through the sympathetic nervous system. The so-called inferior renal ganglion sends nerves to all these organs. The question of pain in abdominal viscera has been the object of many theories since the brilliant work of Lennander, who demonstrated by cocain anesthesia that many of the abdominal organs were not sensitive to cutting, to heat, or to cold, but that most of the pain was from the parietal peritoneum. Many have jumped to the conclusion that the sympathetic system does not carry sensory fibers. Such a view is, of course, rendered absurd by the frequency of pain met with in connection with organs supplied by sympathetic nerves. Anatomical investigations are also at hand to show that the sympathetic system is connected with the sensory roots of some of the spinal nerves, in the case at hand with the lower dorsal and upper lumbar. Our special investigations along this line will be published in the near future.

We have long noted that pain is not only present in the epigastric region, but in the region of the ovaries in diseases limited to the kidney. By means of the artificial reproduction of pain by distending the renal pelvis with fluid, as originally suggested by Kelly, it is found that, in a very considerable number of patients, the pain is not felt in the region of the kidney, but in the ovarian region. Fully 25 per cent. of the patients will show distribution of this character. In some cases with definite ovarian pain, due to gross lesions of the

ovaries, injection of the kidney will reproduce the pain, but in many cases will not do so. It would seem that individuals may have different anatomical nerve relations. Attention is called to this matter here merely because, so far as known, it has never previously been discussed. Contrary to most statements, we have found that with disease of the ureter the pain is likely to be very much the same in its distribution as with renal trouble. From all this it is seen that a very wide distribution of pain may occur from kidney troubles, and every case must be carefully and completely investigated. The injection method produces the pain by distention of the pelvis alone, yet it seems to be capable of producing a pain like that due to any condition of the kidney. Many, perhaps most of the acute attacks of colic referable to the kidney, are not due to any obstruction to the outflow of urine. As suggested in the chapter on Movable Kidney, many of these pains are doubtless due to dragging on the renal pedicle. The causes of pain in idiopathic nephralgia are obscure; some cases would seem to be due to congestions and edema of the kidneys. With a perfectly free outflow of urine, occasionally most severe colic in the kidney from leaving a renal catheter in place for several hours is seen. This would seem to be pain due to violent contraction of the ureter. It is possible that some of the lesions which occur in the kidney may reflexly stimulate the excretory part of the kidney and the ureter to abnormally violent contraction. The development of intestinal colic and also pain in the bladder under like conditions is familiar to all.

This distribution of pain applies to both the cases with colic and those in which the pain is continuous. In colic the pain may last from a few minutes to several days. The marked upsetting of the gastro-intestinal tract and frequent abdominal distention would indicate many of these conditions to be likewise brought about by reflex influence through the nerves.

Having thus gone into detail to show that pain is a most important symptom, we would like to state with equal emphasis that with grave lesions of the kidney it may be entirely absent, a fact which has been dwelt on in a number of chapters in this book. This is particularly true of tuberculosis of the kidney, where the initial symptoms are, as a rule, from the bladder. In many cases pain in the kidney or from the kidney never occurs in the entire course of the disease.

Symptoms from the bladder of the most varied type, as already indicated, may occur where the disease is renal and the bladder normal. In many cases, however, the disease, primary in the kidney, has also involved the bladder. It is, therefore, of great importance in cases where the symptoms may be only frequency in voiding, pain in voiding, difficulty in voiding, and even

bladder retention, to bear in mind that the kidney or kidneys may be the source of trouble.

Bladder Symptoms.—The condition of the urine sometimes attracts the patient's attention to abnormal conditions of the bladder, just as it does in disease of the kidney. Pain is present in a great variety of diseases of the bladder. It is usually located in the bladder itself, frequently at its neck, but it takes the form often of general abdominal pain, which may be constant or in attacks, present before, during, or after voiding. Pain in the bladder or in the abdomen in the region of the bladder arises also in many conditions of disease of the neighboring pelvic organs. Whether this is due to congestion or to direct pressure of the organs, as usually stated, or to reflex nervous influence such as we have outlined from the kidney, is not known. It is of interest in this connection that pain in the bladder may not be present in some of the most severe inflammatory diseases of the organs. In one case of new growth the pain may be intolerable, in the next no pain whatever. Absence of pain is, however, the exception. It has been frequently noted in cases of tabes and other spinal cord diseases and injuries that there may be no sensation in the bladder, either from pain or from the usual feeling which induces voiding.

In addition to pain the well-known symptom of burning and frequency of micturition is found in a great variety of conditions.

Frequency in voiding without pain or with it is a common vesical symptom present with many organic diseases of the bladder, also present in certain neuroses of the bladder, also determined by the quantity and character of the urine which collects in it. With polyuria there is necessarily frequency of bladder emptying. Men are said to void oftener in the 24 hours than women. The frequency will depend to some extent on the amount of fluid ingested and the condition of the skin, the temperature of the surroundings, and so forth. In the chapters on Physiology of the Bladder and Nervous Disease of the Bladder will be found a full description of these conditions. Frequent voiding may mean chronic retentions, as in cases of urethral stricture and enlarged prostate. In some cases we have the so-called paradoxical incontinence. Retentions of the urine, however, are by no means limited to cases where there is obstruction to the outflow of urine. They are invariable in spinal cord injuries, are often present in tabes and multiple sclerosis, occur not infrequently after injuries and various traumata. In this last class should be placed the retention so often met with after operation. It should also be borne in mind that chronic retentions of the bladder may soon lead to serious interference with the kidney function. This was first pointed out by Guyon and Albarran (*Arch. de méd. exper.,* 1890, ii, 181); these authors showed that, with reten-

tions of urine, there was always congestion of the entire urinary tract. They showed furthermore that distentions of 60 hours could be followed by dilatation of not only the ureter and the pelvis of the kidney, but also of the renal tubules. With such conditions it is easy to understand how there may be general symptoms of renal insufficiency due to bladder retention. Retentions may follow slight diseases of the bladder, or the surrounding organs, notably the pelvic organs in both male and female. Some retentions of the functional character are unquestionably due to sphincter cramp, others beyond any question are due to inhibition of the detrusor muscle of the bladder.

Incontinence of urine may follow many organic diseases of the bladder; it may be due to weakness of the sphincter muscle; or it may often be of nervous origin (see Chapter on Nervous Disease of the Bladder).

It is not uncommon in bladder diseases to have pain in the urethra. It is also possible when the ureter or its orifice are involved to have pain referable to the kidney.

Urethral Symptoms.—Various conditions of the urethra lead to pain in the urethra itself and in the bladder. The characteristic symptoms of urethral inflammation are burning and distress associated with the voiding of urine in cases of urethritis. In a posterior urethritis in the male, as well as in the female, there may also be frequency of voiding and marked strangury and pain on voiding. Retentions, incontinence, and various other symptoms we are accustomed to consider as bladder symptoms, may arise when the disease is entirely in the urethra. Marked urethral symptoms may be met with from disease of contiguous genital organs; in the male the prostate is the chief offender; in women a great variety of pelvic conditions; especially notable is the influence of the pregnant uterus. We wish to say, however, in this connection, that, in our experience, we have found that the so-called reflex conditions, giving rise to pain or some other symptom in the urethra and bladder, when the condition is really pelvic, are not so very common. In most of the cases so classified there is real urethral and vesical trouble, although it may be slight.

From all this it is evident that a careful history, both general and regional, must be taken and fully considered in every case where there is reason to suspect disease of the urinary organs. Such a history may point clearly to the diagnosis, and forms, with the examinations, indispensable data upon which to base our treatments.

CHAPTER XIV.

SURGICAL OPERATIONS ON THE KIDNEY.

GENERAL CONSIDERATIONS.

The surgery of the kidney is peculiar for many reasons. Operations upon it can be brought under four classes:

(1) To correct a misplacement; in this resembling operations for displaced or prolapsed uterus.

(2) To open and drain an infected kidney; in this resembling operations upon the vermiform appendix or for a pelvic abscess.

(3) To remove foreign bodies, calculi, etc.; in this resembling operations for removal of stones from gall bladder or urinary bladder.

(4) To remove the kidney; in this resembling an extirpation of the uterus, and, in that there are two kidneys, each of which alone is capable of carrying on the entire work of economy, resembling the extirpation of an ovary.

And yet with all these strikingly similar features the surgery of the kidney presents many essential peculiarities which distinguish it from the surgery of all other organs. These are determined by peculiarities of its anatomy and physiology. First, it is a double organ, each kidney being capable of carrying on the entire renal function in case of necessity; it differs, however, from most other bilateral organs regularly attacked by surgeons (the ovaries, testicles, thyroids, eyes, and ears), in that none of these are essential to the life of the individual as a whole, while a certain amount of kidney tissue is indispensable to life and its entire removal means certain death.

The circumstance that lends such great interest to renal surgery is the fact that if one kidney be so diseased as to be worthless or even a menace to the life and health of the individual, it is safe to remove the diseased organ if the other is sound.

Just here the delicate judgment of the surgeon comes into play. Is one kidney sound? If not so, yet is it sufficiently intact to carry on the functions of the body if the side markedly diseased is removed? Such a decision in the

presence of some disease on the opposite side often involves nice discriminations between affections limited to the pelvis and those which affect the kidney tissue proper. In the former an operation is safe, in the latter the risk is great. Then, too, it is needful to distinguish, in the group of parenchymatous and interstitial affections, those milder disorders associated with albumin and hyalin and a few granular casts, which may run a protracted course, from those graver cases, where the strain upon the kidney constitutes a greater risk, both from the immediate effects of operation and the remoter effects of carrying on the entire work of elimination; for it must not be forgotten that it often happens, as in hypernephromata, for example, that the kidney which needs removal is only partly affected and often doing good work. One of the peculiarities, which is also the greatest charm of this kidney work, is the delicacy of the manipulations needful to discriminate between the physiological and pathological condition of the two kidneys, calling for the use of cystoscope and the ureteral catheter, instruments confessedly demanding special training and special skill for their effective use.

Furthermore, the problem is, in part, always one for microscopic and chemical laboratory research, and the diagnosis is reached, not by simple palpation, as in fibroid tumor of the uterus, but from a careful study of the character of the secretions. This fact opens up a field for discussion and reveals differences of opinion in each case, not only as to which form of disease the findings indicate, but, what is of equal importance, as to the grade of the disease present? An early or a later stage?

In the kidney, too, we often find more than one affection simultaneously, as, for example, stone and infection, displacement and hydronephrosis, and hydronephrosis changing over into pyonephrosis.

So, in considering the treatment of kidney trouble, the surgeon has not only to take into account the pathologic processes, but must also be acquainted with their extent and location. In every case it is by careful reviewing of all the data that he decides whether to operate or not; and, if the former, what kind of an operation to do.

Preliminary Preparations.—The patient should be kept under observation long enough to secure all important data. This, as a rule, takes from three to seven or ten days, and may take longer if the patient has to be handled with great care on account of depressed health. There are also exceptional cases where it is proper to let the patient enter the hospital and be operated on in one or two days.

Infected cases should be given urotropin beforehand. It is also valuable in mildly infected cases to reduce or eliminate the infection. It is a good plan to

irrigate an infected bladder, or an infected pus kidney, for some days before operation, washing it out through the renal catheter.

Where a patient is seen carefully at least several times beforehand, the operator gets a better idea of the case, and, when there are several troubles, as in an infected kidney with a cystitis, he can determine which is more important and which demands immediate relief, or whether simultaneous operation on both organs ought not to be done.

The great advantage of having the patient under the direct supervision of the surgeon for at least two periods of 24 hours each just before the operation is that exact data may be secured regarding the amount of urine being secreted, the amount of urea passed each 24 hours, and the abnormal elements found in it. With these observations are associated others of a more exact nature described in the chapter on Examination of the Urine.

Evacuation of the Bowels.—The bowels must be completely emptied before the operation and regulated so as to avoid any explosive action and the ineffective discharge of large amounts of fecal matter within a short time after the operation. Avoiding, too, the serious effects of intestinal auto-intoxication from accumulations of fecal matter. Compound licorice powder, ʒi to ʒiv, or Ext. cascara sagrada m xx to ʒi, or calomel in quarter-grain doses every 15 minutes, 8 doses given in two hours, 36 hours before operation, and followed by a mild saline purge, will effectually empty the intestinal tract. Enemata of soap suds and water given 4 to 5 hours before operation will suffice to evacuate completely the lower bowel. With attention and preparation this most important emunctory supplementing the action of the kidney is in condition to perform its function and relieve the kidneys of any stress of vicarious work.

The Skin.—The skin should be acted upon by warm baths and rubbing so as to get it thoroughly clean, getting the pores open and active, and making the whole organ soft and capable of fulfilling its function as an emunctory.

Rest in Bed.—The next important effort in regard to preliminary treatment is to secure absolute rest in bed for a few days before operation. This quiets the nervous system, rests the heart and all the vital organs, the kidneys included, and makes for the highest possible resistance at the time of operation.

Cleansing the Patient for Operation.—We believe that all cleaning up of the skin for the operation can be best done on the operating table. This can be carried out in the period while the patient is going completely under the influence of the anesthetic. In this way valuable time is saved and the anesthesia is not unduly prolonged. If the condition demands a serious and pro-

longed operation, and if the patient's condition is bad, then the cleaning up may to advantage take place before any anesthetic at all is given.

In cleaning we advise making a lather with a thin, liquid, green soap and shaving the entire field of operation and the surrounding area.

The next step is to rinse off the skin with a little soap and water. The skin is then thoroughly gone over with alcohol, 95 per cent., and then with ether. Then an ordinary 10 per cent. solution of iodin is painted over the entire region concerned. This whole procedure takes about 4 minutes, and can be done either before or after anesthesia.

The cleaned skin is now suitably separated from the surrounding skin by sterilized towels and sheets and covered over until the operator is ready.

Position of the Patient.—It is important for the rapid and successful performance of the operation that the patient should be in the best position possible for the exposure of the kidney. This is secured by placing her upon one of Edebohls's cylinder rubber bags (about 10 inches in diameter and 20 inches in length), which should be blown up tight and the patient extended across it with her face toward the table, so as to place the bag across the upper abdomen (Fig. 173). Then letting out a little air from the bag, the surgeon can see that the patient's body inclines a little to the opposite side, while the side to be operated upon is tilted up and exposed. In a large tumor of the kidney, when a large incision is necessary, the side should be reached more from the table and the back so as to leave a larger free space in the middle abdomen where there is no pressure. In the hypernephromata of the larger size it may even be necessary to have a patient lying almost flat on the back, when a long abdominal incision is made to expose the tumor. The operator should stand on the side of the affected kidney—that is, if the right kidney is to be operated on he stands on the right side of the patient; if the left kidney, at the left side of the patient—and this places him always facing the patient.

Instruments.—The instruments to be prepared are all boiled and put in large pans which have been sterilized in the autoclave, where the dressings, too, are sterilized. We sterilize our catgut by the well-known cumol method, and preserve it in alcohol. The operator and his assistants sterilize their hands by scrubbing them with soap and hot water, then putting them into a solution (saturated) of permanganate of potash, then into a solution (saturated) of oxalic acid, and then into bichlorid of mercury, 1 to 1,000; rubber gloves are then put on. We find the pebble-grained, close-fitting, thin gloves of the greatest help. The operator and assistant wear long gowns with sleeves, also caps and gauze pieces to go over the nose and mouth.

Anesthetic.—The choice of an anesthetic is most important, as there may

result serious changes in the kidneys due to its irritation. An irritation of small importance in normal kidneys may in renal insufficiency so aggravate conditions as to bring about uremia and death.

Ether may be given, if used with care, but never by an inexperienced man. In a prolonged anesthesia and given excessively it is dangerous. In our own private practice for two years practically every case of ether anesthesia lasting half an hour or more has been followed by the appearance of hyalin casts in the urine lasting for a day or two. Nitrous oxid with oxygen is now more ideal and more harmless and may be kept up one or two hours by a skillful anesthetist. The objection to NO with O is that it requires greater skill on the part of the anesthetist to keep the patient well under control, and occasionally there is not sufficiently complete relaxation. A highly nervous or an alcoholic patient may even struggle. Indeed, there seems quite a wide individual variation as to the susceptibility to this anesthetic. Under such circumstances a happy medium is found in giving NO with a little ether in minimum quantity (a drachm or two during an hour's operation).

INCISIONS TO EXPOSE KIDNEY AND URETER.

Variety of Incisions.—Since 1869, when Simon ("Chirurgie der Nieren," 1871) showed the possibility of renal surgery, there have appeared many contributions to the literature dealing with the method of best exposing the kidney for the various operations done upon it. Since the very beginning of this development two principal routes have been advocated, the lumbar extraperitoneal and the transperitoneal anterior. Here, as elsewhere, where the question is a difficult one and varies with the special case and special indications, there are a great multitude of methods, and every surgeon has his own. Not to estimate the value of these procedures, but for the sake of their historical interest, we recall some of them, beginning with Simon's:

Skin incision 9-10 cm. long along outer border of M. sacro-spinalis, beginning over XI rib, crossing XII, and extending down in a perpendicular direction to middle of space between XII rib and crest of ilium. Latissimus cut through, M. sacro-spinalis pulled aside, and incision carried upward, exposing XII rib. Both leaves of fascia lumbo-dorsalis and M. quadratus lumborum split. Transversalis fascia then pierced and perinephritic fat exposed. The twelfth nerve and vessels and first lumbar nerve are cut during operation. Care must be taken to avoid cutting into the pleura, which may extend at times to the I lumbar vertebra. Owing to the insufficiency of space gained in this

way, and to the danger of hemorrhage, few men have followed this plan, and the abdominal route is preferred.

Czerny[1] sought to gain room by placing Simon's incision further forward along the anterior border of the M. quadratus lumborum. He resected the outer third of XII rib, and, later, adopted a more oblique incision, 15 cm. in length, running immediately below and parallel to the XII rib.

Skin incision oblique, beginning at the XII rib and running downward and forward toward crest of ilium. All tissues down to fatty capsule cut during operation.[2]

Küster,[3] prompted by the same desire to gain room, recommends an incision running in the middle between the XII rib and the crest of the ilium, parallel to the latter.

V. Bergmann in the same discussion recommends Simon's incision with lateral secondary cut in the form of a ├.

Skin incision made along the outer border of the sacro-spinalis upward to the level of X or XI rib. The XII rib then resected. In operation for suspension of the kidney its upper pole is attached to the periosteum of the resected rib.[4]

Skin incision made along outer border of sacro-spinalis, cutting all tissues from XII rib to crest of ilium. If more room is required, the incision is enlarged either parallel to XII rib or along upper border of ilium, resulting in either T-shaped or L-shaped incision.[5]

Skin incision made along outer border of sacro-spinalis, beginning 2 to 3 fingers' breadth above lower border of XII rib, and extending down to iliac crest. All structures cut during operation. (Suspension—last rib resected and suture of capsule of kidney to periosteum.[6]

Incision from XI rib to middle of crest with transverse incision higher or lower (costal incision; iliac incision; ilio-inguinal incision), or both, producing the door-wing incision [or double door-wing incision I.[7]

Skin incision made in a vertical direction, midway between XII rib and crest of ilium, along the outer edge of the M. quadratus lumborum for a dis-

[1] Czerny, *Centralbl. f. Chir.*, 1879, vi, 737. Also *Arch. f. klin. Chir.*, 1880, xxv, 858.

[2] Hahn, *Centralbl. f. Chir.*, 1881, viii, 449.

[3] E. Küster, *Berl. klin. Wochenschr.*, 1883, xx, 604.

[4] Ceccherelli, *Centralbl. f. Chir.*, 1884, xi, 742. Also, De Paoli, *Centralbl. f. Chir.*, 1885, xii, 910.

[5] Poncet, *Province méd.*, 1887, i, 563.

[6] Duret, *Jour. des sciences méd. de Lille*, 1888, xi, pt. 2, 49; 73.

[7] Bardenheuer, Schmidt, "Beitrag zur Casuistick der Nierenchirurgie Mitteilungen aus dem Kölner Bürger-hospital," Köln, 1890, Hft. 5.

tance of about 9 cm. It divides all the underlying tissues exposing the perinephritic fact which is torn through to the kidney.[1]

Skin incision extending from outer border of rectus at the level of the umbilicus around to the lateral border of the M. sacro-spinalis.[2]

Skin incision made along the outer edge of sacro-spinalis, which should in all cases extend the entire distance between the lower edge of the XII rib and the crest of the ilium. The incision should be oblique, dividing successively the skin, superficial fascia, tendon of the latissimus dorsi, and the conjoined tendon of the internal oblique and transversalis muscles. The fatty capsule is exposed and penetrated by a small incision down to the kidney substance proper. (In suspension the incision is made along the entire length of the convexity of the kidney and the capsule drawn out of the wound. The excess of the capsule is trimmed off, exposing the kidney for suture.)[3]

Curved incision running obliquely downward and forward from the angle between M. sacro-spinals and XII rib to the crest of the ilium.[4]

Where much room is wanted, D'Antona recommends the so-called "oblique lateral incision" beginning at the upper border of the XII rib at a point where the sacro-spinalis crosses the rib, extending downward and forward toward a point between the outer and middle third of Poupart's ligament. All three muscles are severed.[5]

Skin incision from a point about one inch inside the anterior-superior spine extending upward and backward $4\frac{1}{2}$ inches, parallel with the fibers of the M. obliquus externus. The abdominal muscles are then separated, as in McBurney's method. Having reached the peritoneum the index finger is pushed backward to the perirenal fat, and readily sweeps the peritoneal sac off the front of the kidney.[6]

In his paper, "Method of Exposing Kidney without Division of Muscles, Vessels, or Nerves," Robson recommends a skin incision beginning at the inner side of the anterior-superior spine of the ilium, extending backward in an oblique direction toward the tip of the last rib. The fibers of the external oblique are then split and retracted, exposing the fibers of the internal oblique, the muscular fasciculi of which are split in a line between the IX costal cartilage and the posterior-superior spine of the ilium, in which position they are longer than in front of or behind that line. When the fingers are pushed

[1] Keen, "Ann. Surg.," 1890, xii, 81.
[2] Pean, *Ann. d. mal. d'org. génito-urin.*, 1894, xii, 393.
[3] Edebohls, *Am. J. M. Sc.*, 1893, cv, 247.
[4] Albarran, *Rev. de chir.*, 1896, xvi, 882.
[5] D'Antona, *Compt. rend. Cong. internat. de méd.*, 1897, v. 302.
[6] Abbe, *Ann. Surg.*, 1897, xxv, 744.

through the internal oblique to split it, the fibers of the transversalis are pierced and can be retracted along with the oblique muscle. A diamond-shaped space is formed, at the bottom of which is seen the transversalis fascia, which is then incised, exposing the perirenal fat, and on pushing the fingers through this the kidney is easily reached. The whole hand can then be introduced into the opening, and the kidney brought out and examined with fluoroscope for calculi.[1]

In cases where it is necessary to extend the opening for ureteral work, the lower fibers of the external oblique are split toward Poupart's ligament. This exposes the ureter down to the bladder.

Skin incision directed obliquely across the lumbar region, beginning an inch above and in front of the anterior-superior spine, continuing upward and backward to the angle of outer edge of sacro-spinalis, one finger's breadth below the XII rib. An incision of such extent is not often necessary, but it should run always between these points. At times the incison is extended over the XII rib, especially if necessary to resect the rib. "Snicking" the outer border of the M. quadratus lumborum is sometimes useful.[2]

Anteriorly the incision may be carried parallel to Poupart's ligament (an inch above it) as far forward as the internal abdominal ring. Part of the last dorsal or ilio-hypogastric nerve may be resected if necessary.

Skin incision made through the abdominal wall along semilunar line and including the peritoneum; this is done in order to investigate the other kidney. The peritoneum is then closed and a second incision made from the middle of the first incision, extending at right angles outward and backward until the kidney is reached and well exposed. The peritoneum is stripped back so as to approach the kidney extra-peritoneally.[3]

Skin incision either transverse, running from outer border of M. sacrospinalis to the anterior axillary line about 2 cm. below the XII rib, or perpendicular, then along the outer border of the sacro-spinalis beginning over the XII rib and extending down to the middle between rib and crest of ilium.[4]

Skin incision according to McBurney is as follows:

I. A vertical cut $2\frac{1}{2}$ inches in length is made just external to the semilunar line and carried through the peritoneum, for the purpose of examining the other kidney. The incision is then carried outward and back parallel to costal border as far as the external border of M. sacro-spinalis. The original in-

[1] Mayo Robson, *Lancet*, 1898, May 14, 1315.
[2] Morris, "Renal Surgery," 1898, p. 116.
[3] J. S. M'Ardle, *Dublin Jour. Med. Sci.*, 1898, xv, 1; 193.
[4] Tillmann, "Lehrbuch der Chirurgie," 1898.

cision into the peritoneum may be closed, if thought best, and the operation conducted entirely extraperitoneally. More room is gained by a vertical prolongation of vertical incision.

II. In some cases a simpler mode of procedure is an incision parallel to XII rib and ½ inch below, beginning at the outer border of M. sacro-spinalis.

III. For movable kidney the incision is begun at outer border of M. sacro-spinalis (does not state at what level) and continued obliquely downward and forward four or more inches.[1]

Skin incision perpendicular and about 8-10 cm. long. It runs along the outer border of the M. sacro-spinalis from the XI rib to the middle of the space between the lower border of the XII rib and the iliac crest. After cutting through the paniculus adiposus and fibers of the M. latissimus dorsi, the lumbo-dorsal fascia is incised and the outer border of the M. sacro-spinalis retracted. Then the M. quadratus lumborum and fascia transversalis are split, which exposes the perirenal fat. This is done by blunt dissection and the XII thoracic and I lumbar arteries and nerves can be preserved.[2]

The retro-peritoneal lumbar abdominal incision of König extends from the XII rib along lateral border of sacro-spinalis toward iliac crest, then curves forward toward the umbilicus until the outer border of the rectus abdominis is reached.

Incision beginning at the anterior border of the sacro-spinalis about 1 cm. below XII rib parallel to costal margin or somewhat obliquely downward. It is of varying length, according to its purpose, and severs all three muscular layers. To gain more room the outer portion of the lower ribs is resected, and it is remarkable how much room is obtained in this manner.

Schede considers resection of the last two ribs indicated in all operations where the upper pole is exposed with difficulty. The pleura is rarely injured, and, even if wounded, no serious trouble is experienced. In his opinion, contrary to the usual teaching, there is little danger connected with an injury to the pleura.[3]

This great divergence in methods of approaching the kidney does not depend on caprice, but on the fact that the kidney lies in a difficult place to get at and no one typical incision will meet all the conditions encountered. The incision for simple suspension is a different one from that required in safely handling a large renal tumor. Efforts to systematize the approaches to the kidney have not met with the success achieved in other parts of the body. It

[1] Johnson, *Ann. Surg.*, 1899, xxix, 334.

[2] König, "Lehrbuch der Speziellen Chirurgie," 1899.

[3] Schede, "Handbuch der praktischen Chirurgie des Unterleibes," 1901, iii, part 2.

is much easier to lay down rules governing the approach by incision to the pelvic organs and most of the abdominal viscera than to the kidneys. Here, as elsewhere, certain ideals are aimed at. The incision used, while giving free and safe exposure of the organ, should sacrifice a minimum of muscle, vessels, and nerves. It should be large enough to admit free handling of the kidney with the hand. The question of post-operative hernia does not play the part that it does in incisions into the peritoneal cavity from the front. Cutting of nerves, however, is followed by disagreeable paresthesias, anesthesias, and, in some cases, pain which persists for years.

We have purposely confined ourselves to a description of the lumbar and extraperitoneal incisions, because the abdominal incisions have proven signal failures, and are now resorted to by few surgeons except as an exploratory device; yet even here the advantages are largely illusory. In infected cases there is the danger of peritonitis; in all cases greater shock. In the majority of kidneys the pelvis is posterior and the posterior route leads most surely to the hilum.

In determining the lumbar incision the operator should be guided by the body form of the individual, in the first place; in the second, by the nature of the operation. It is astonishing how great the variations are in individuals in the distance between the last rib and the crest of the ilium. Note in Figure 236 the long distance in the slender, long-bodied, movable-kidneyed woman and compare with it the relations in the short-bodied, thick-set man (Fig. 235). The retroperitoneal position of the organ is at once the difficulty and the safety of the operation, the despair and the hope of the operator. It is this retroperitoneal position which, with the abandonment of the transperitoneal route, forces the lateral or postero-lateral incisions upon him. The kidney operation is often easy, provided the exposure is perfect, but the space needed to palpate a normal kidney is very different from that required in exploring an enlarged, inflamed kidney for stone through a nephrotomy, or in removing the kidney where its upper pole is densely adherent. Considering these factors in more detail we have:

Influence of Topography.—The influence of the topography of the lumbar region is limited to one condition, i. e., the length and direction of the XII rib. The main object of the incision should be to come as near as possible to the kidney and yet not injure the pleura. For this reason, in cases of normal length and direction of the XII rib, the skin incision is begun in the intercostal space between the XI and XII ribs at a distance of about 6-7 cm. from the posterior middle line and extended obliquely downward and outward, as shown in Figure 173, until about 4-5 cm. from the iliac crest. The length of the skin incision

need not exceed 12 cm., and for simple nephrorrhaphy an incision of 8 cm. will often afford sufficient room.

If the XII rib be short so as to resemble the transverse process of a lumbar vertebra, the incision had best be begun just over the tip of that rib. A glance at Figure 173 will explain that the reason for this suggestion is that, after having determined by this cutaneous incision the exact position of the XII rib, it will be less difficult to accurately map out the limit of the pleura.

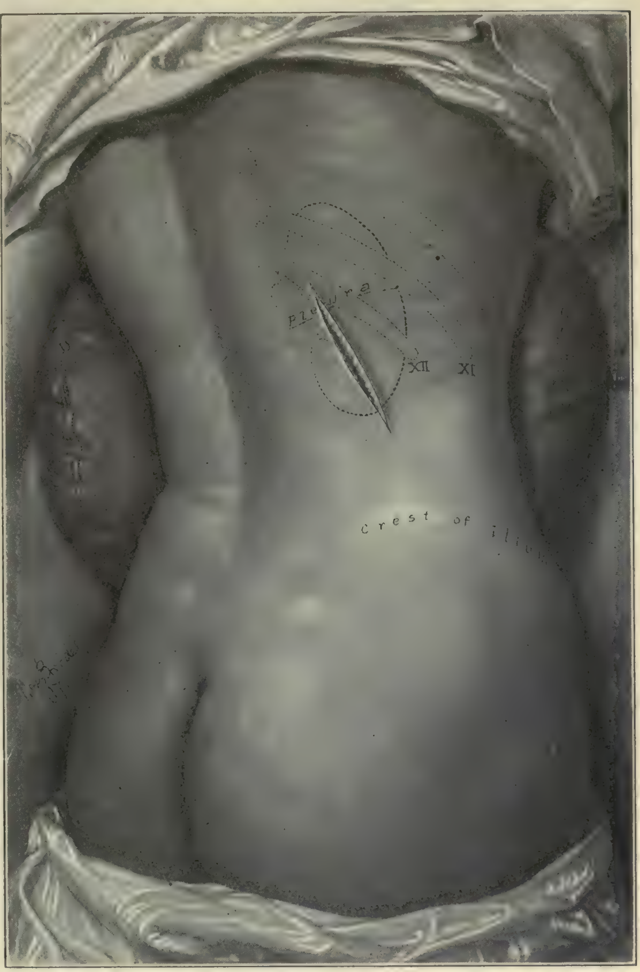


Fig. 173.—Position and Length of Incision for All Minor Operations on Kidney. For example, suspension of kidney, nephrotomy, pyelotomy and simple nephrectomy. Note how incision is immediately over superior lumbar trigonum. The posture of patient on kidney bag is the ideal one. The body lies on bag so that the side operated on is uppermost, and so stretched that the distance between the last rib and the crest of the ilium is increased.

The Kind of Operation.—The nature of the operation, whether minor or major in character, determines to a great extent the length and direction of the incision. In every instance the skin incision ought to begin at the point above described; in minor operations it need not exceed in length that pictured in Figure 173, while in major operations it should be

considerably longer and curve more anteriorly, parallel to the lower ribs (Fig. 183).

If the kidney is of ordinary size, and in its usual place, it is best approached through the superior lumbar trigonum, while, if we have to deal with a kidney converted into a tumor mass extending far below the costal margin and projecting for some distance laterally, the operator requires more room than allowed by the superior lumbar trigonum. In such instances there are three ways to gain the desired exposure:

(1) To make a gridiron incision through the broad abdominal muscles over the point of greatest prominence, in the manner described by Mayo Robson, and, if this prove of insufficient size, to enlarge it by means of an incision through the muscles toward the center of the superior lumbar trigonum (frying-pan handle) (Figs. 189 and 190).

(2) To commence the incision by bluntly opening the superior lumbar trigonum, and then enlarging it in an oblique downward direction by means of an incision through the muscles parallel with the lower ribs, i. e., the first procedure reversed.

(3) When these two procedures do not make sufficient room, or when it is found that the kidney is high up and densely adherent, we have found the procedure recommended by Schmidt, Schede, Lange, and others an excellent one. This consists in a resection of the XII and, if need be, the XI rib. By removing this unyielding barrier the exposure of the upper pole of the kidney is remarkably facilitated (Fig. 191).

Approaching the Kidney through the Superior Lumbar Trigonum in Minor Renal Operations.—On account of the ease with which a kidney can be approached through the superior lumbar trigonum, and also for the reason that there is no necessity for cutting or splitting any muscle, this procedure is indicated in such operations as fixation, opening of abscesses, removal of stones of moderate size, and even of large stones, provided their presence has not caused the kidney to be too densely adherent, in which case a larger incision is better.

After preparation and anesthesia, as indicated at the beginning of this chapter, the patient is put on the table either perfectly prone, or, better, partially on the opposite side. The Edebohls bag (Fig. 173) is a material and great aid in the exposure. It should be so placed as to increase to the uttermost the distance between the last rib and the crest of the ilium. The operator readily locates the superior lumbar triangle pictured in Figure 175 by palpating the region between the crest of the ilium, the spine, and the last rib. It is represented by the softest spot in the angle formed by the rib and the

sacral spinalis muscles. The incision is carried down to, and not through, the superior lumbar triangle.

The skin is incised, as shown in Figure 173, beginning somewhat above the middle of the XII rib (in cases of short XII, just over its tip). In its course downward it is curved slightly forward in the direction of a point midway between the spinous processes of the lumbar vertebræ and the anterior-superior spine of the ilium. Its inferior end is then some distance to the side of Petit's triangle. It is not necessary to carry it further than within 4 cm. of the iliac crest.

After having retracted the skin and subcutaneous fat the superficial layer of muscles is exposed (Fig. 174); above and medianward we see the M. latissimus dorsi, while below and laterally there is the M. obliquus externus. The upper part of the posterior fibers of the latter is covered by the most lateral portion of the latissimus. The skin and fat incision renders visible about equal areas of both muscles. In following the posterior border of the internal oblique in an upward direction the tip of the last rib is felt, or, in cases of short XII the tip of the XI is felt, though some distance to the side. Below, the two flat muscles are seen to separate, leaving a triangular space (Petit's triangle), which is easily recognized by the fascia covering it, to which the fat seems somewhat more intimately adherent than elsewhere. No vessels or nerves are seen, with the exception of two or three small cutaneous twigs emerging through the body of the latissimus, some distance from its lateral border (see Figs. 174 and 175), and a larger one piercing the fibers of the external oblique. This is the lateral cutaneous branch of the XII nerve accompanied by the corresponding vessels whose terminal branches are distributed over the lower part of the lateral abdominal wall, the crest of the ilium, and the thigh. Before the nerve emerges from the muscles it gives off motor twigs to the muscle bundles in its vicinity, but for the rest of its course it contains only sensory fibers.

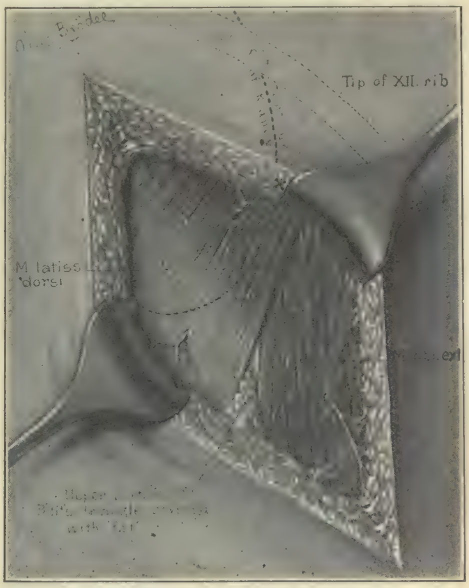


FIG. 174.—DETAIL OF FIGURE 173. Superficial layer of muscles.

Figures 192 and 193 give a clear idea of the lateral cutaneous nerves and vessels.

The next step in the operation is the exposure of the superior lumbar trigonum. This is accomplished by drawing the lateral border of the M. latissimus dorsi medianward (Fig. 175), and, as the connection of this portion of the muscle with the underlying structures is very loose, no difficulty is experienced in freeing it for a considerable distance (Fig. 176). Along the outer border of the M. sacro-spinalis there are a number of vessels emerging from the depth, which send branches into the latissimus, thus affecting a

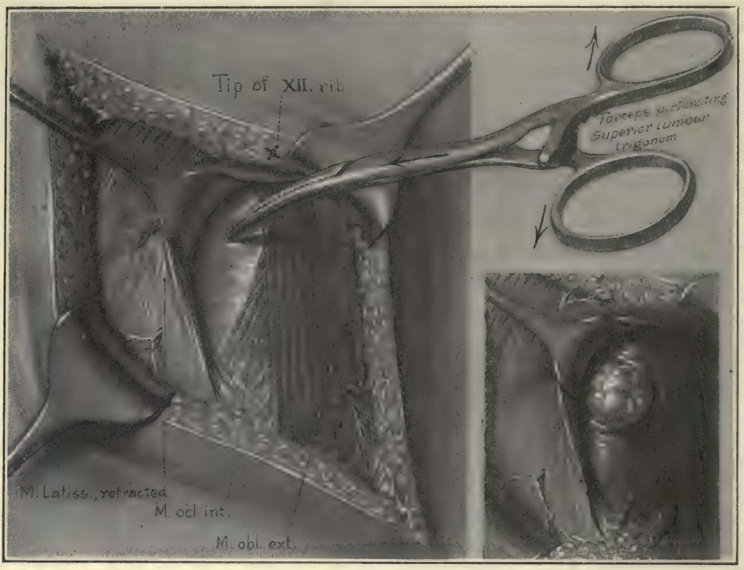


Fig. 175.—Exposure of Superior Lumbar Trigonum by Retraction of M. Latissimus Dorsi. Forceps ready to perforate fascia over trigonum. Smaller figure to right shows puncture of lumbar fascia with clamp; the pale lump of fat protrudes.

firmer connection of that muscle to the underlying structures. Beyond this line it is not necessary to free the latissimus.

In some instances the latissimus reaches very far forward, and it is advantageous to cut it, which is best done at right angles to the muscle fibers, parallel to and just below the XII rib. It is often of advantage not to go to the edge of the latissimus, but to split its bundles in a longitudinal direction. This procedure carries one down to the superior lumbar triangle (Fig. 177).

Having drawn aside the latissimus, as shown in Figure 175, the lumbar fascia over the superior lumbar trigonum is at once exposed. There is often a

small amount of fat covering it, which is continuous with the mass of fat situated in the region of Petit's triangle. The upper portion of the triangle is of a firmer consistency than the center and lower part, owing to the presence of the lumbo-costal ligament and ligamentum arcuatum, both of which strengthen the lumbar fascia in this region.

As shown in Figures 174, 175 and 176, the triangle is bordered by the lateral margin of the sacro-spinalis, the last rib, and the external as well as internal oblique muscle. The first and second structures are relatively firm, while the last two are much more yielding. The fascia is then bluntly perforated (see Fig. 175) at a point about $1\frac{1}{2}$-2 cm. below the rib, i. e., a point midway between the subcostal XII and the I lumbar nerves and vessels. The perforation is best done by a pair of curved artery forceps withdrawn opened. A small mass of retroperitoneal fat pouts out of the little hole in the fascia. The opening is then bluntly spread open by means of the fingers in an up and down direction, until there is enough room to admit a hand (Fig. 178). The drawing, Figure 176, by no means represents the maximum space gained, as the opening can be enlarged with ease until there is enough room to handle the kidney. Along the median side of the opening we find in the depth the lateral portion of the M. quadratus lumborum, and if we examine its lower part we find invariably the I lumbar nerve, either as a single or more frequently as a double trunk emerging from underneath the body of the quadratus (Fig. 176). The outer of the two is the N. ilio-hypogastric; the inner the inguinal. The angle at which the nerve runs to the lateral border of the quadratus varies to some extent. As a rule, it seems to run almost parallel to the muscle and does not curve outward until near the pelvic brim. This is, however, only a mechanical dislodgment of the nerve, owing to the opening in the fascia which has been made above it, and which presses the nerve

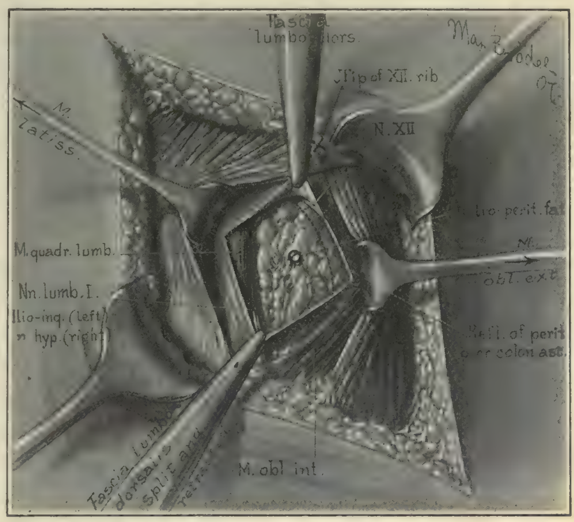


FIG. 176.—LUMBAR FASCIA MORE WIDELY OPENED, EXPOSING RETROPERITONEAL FAT, M. QUADRATUTS LUMBORUM, AND FIRST LUMBAR NERVE.

against the lateral border of the quadratus. In doing fixation of the kidney it is essential to study carefully the course and relation of the nerve to the quadratus lumborum. The kidney if sutured to this muscle should be attached to the upper outer edge, where the ligatures do not include the I lumbar nerve, which should remain below the place of suture, as the constant pulling of the ligature on an included nerve is apt to cause the patient more pain and annoyance than her original trouble. If we lift up the border of the perforated fascia above, we find the subcostal (XII) nerve skirting the upper margin of the opening (see Fig. 176). This nerve runs just beneath the XII rib along the inner surface of the fascia. The lateral cutaneous branch of this nerve is the only one to come in the vicinity of this opening (blunt incision), but, as it is not given off until some distance laterally to the superior lumbar trigonum, it is only visible in exceptional cases, in which case a bifurcation of the XII nerve along the outer border of the opening can be seen. While enlarging the opening with the fingers the muscles are found to yield most easily laterally and below, although the quadratus and sacro-spinalis as well as the costal margin permit of a certain degree of retraction. During this process the nerves and larger vessels are in no way injured (Fig. 178).

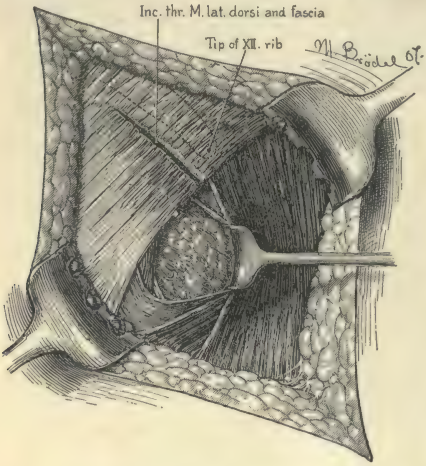


Fig. 177.—Transverse Cut Through Fibers of M. Latissimus Dorsi. Note that incision is parallel to inferior border of last rib. This gives more room when it is necessary to have it.

The mass of fat which presents itself at the floor of this opening is the pararenal fat. It is a portion of an extensive layer of fat situated between the retrorenal fascia and the muscles of the posterior abdominal wall, beginning above the XII rib and stretching as far down as below the iliac crest. It is continuous with the fatty layers in the iliac fossa and anterior abdominal wall, and is often called retroperitoneal fat. The thickness of this fat varies greatly; it may be only a few millimeters deep, but in stout persons it reaches not infrequently a thickness of 2 cm. and more. The blood supply of this fat is derived from small branches of the subcostal and I lumbar artery, which emerge from the cleft between the psoas and quadratus, and also around the outer border of the quadratus. This fat has a yellow-orange color.

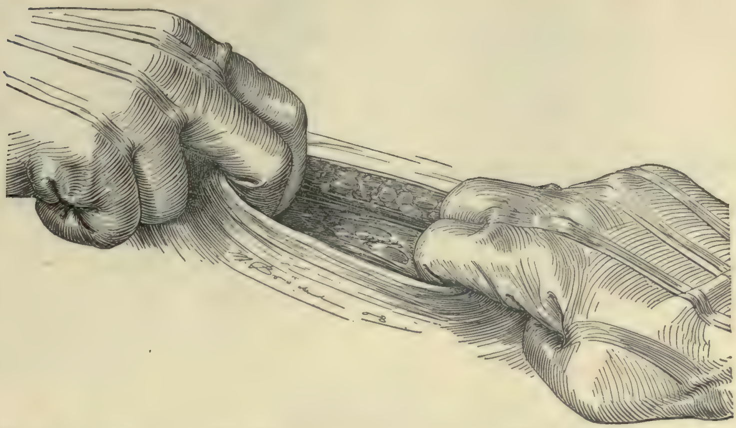


FIG. 178.—BLUNT ENLARGEMENT OF INCISION BY MEANS OF TRACTION WITH THE HANDS. Such enlargement saves hemorrhage and preserves the anatomical structure uninjured.

Between this layer of fat and the kidney there is a second layer, the perirenal fat, or capsula adiposa renis, Gerota's capsule. This is continuous with

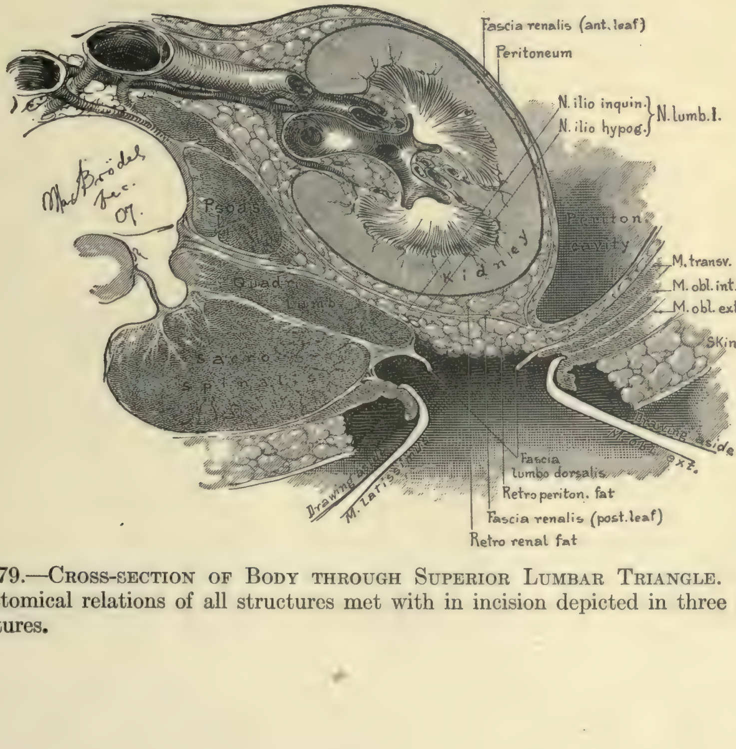


FIG. 179.—CROSS-SECTION OF BODY THROUGH SUPERIOR LUMBAR TRIANGLE. Showing anatomical relations of all structures met with in incision depicted in three preceding pictures.

the fat surrounding the renal pelvis, the vessels, and the ureter, extending down to the bladder and pelvic adipose tissue. These two layers in the region of our incision are separated by the retrorenal fascia (Fig. 179). This fascia is now perforated with a blunt instrument in about the center of the exposed area. It must be borne in mind that the peritoneal reflection is but a short distance anteriorly, and in order to avoid opening the peritoneal cavity it is well to perforate as far back toward the quadratus as possible, and in a direction toward the hilum of the kidney and not its lateral border; and also that on the left side the reflection of the peritoneum reaches further back than on the right, where it crosses obliquely over the kidney almost parallel to the XII rib (Fig. 44). In cases of excessive mobility of the kidney the peritoneal reflection may extend very far back and even cover the whole of the posterior surface of the kidney, forming a distinct mesonephron.

Under usual conditions of an operation upon the kidney it must first be exposed *in situ,* i. e., up under the ribs, and then delivered from its fatty capsule and brought down to the incision in the loin.

It is quite impossible to deliver all kidneys through this incision. In many cases it would mean tearing the kidney in two or tearing it loose from its vascular pedicle. A movable kidney, however, is an exception to the rule. It is often possible to withdraw it from the abdomen without touching it. This is accomplished by applying a number of artery clamps to its fatty capsule and little by little drawing it down. This procedure is shown in Figure 248. One of us—Kelly—has used this for years. It is also described by A. H. Ferguson. The kidney can be thoroughly explored by this procedure.

As a rule, however, the kidney must be approached and freed by more elaborate technique consisting of the following steps: (1) Opening the fatty capsule; (2) detachment of the perirenal fat on all sides; (3) freeing of the upper pole; (4) freeing of the lower pole; (5) delivery of the kidney attached only by the vascular pedicle and the ureter.

Before taking up in detail the actual technique of these procedures, considerations which more closely concern the question of incision and the more general features of exposure must be dwelt on.

In this connection it is important to study the displacements, the degree of tension and possible injury of the large abdominal vessels which may occur during an attempt to bring into view a kidney with a short pedicle.

The aorta and vena cava are anchored to the vertebræ by the lumbar vessels, which curve around the sides of the vertebral column (Fig. 180). The lumbar arteries are long on the right side and short on the left, while the arrangement of the corresponding veins is reversed. The aorta is, therefore, an-

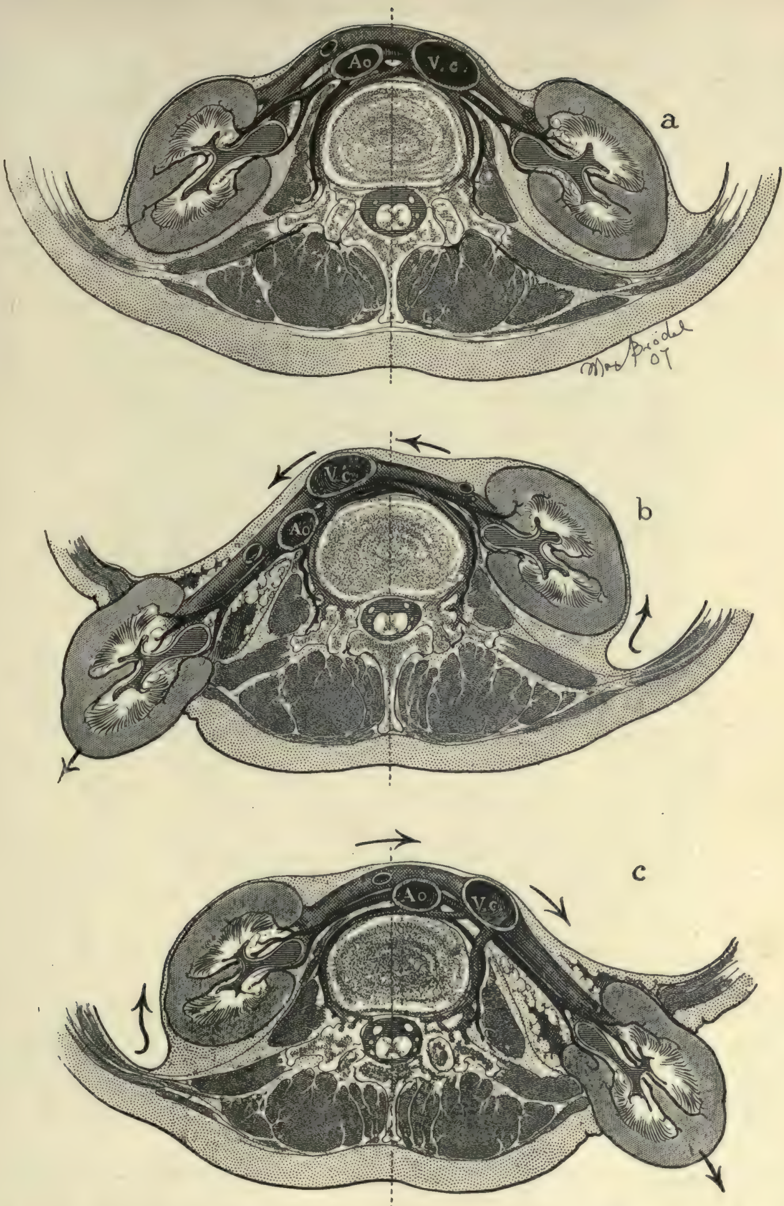


FIG. 180.—TRANSVERSE SECTIONS OF BODY SHOWING DISPLACEMENTS OF AORTA AND VENA CAVA PRODUCED BY DELIVERY OF KIDNEYS THROUGH LUMBAR INCISIONS. a, represents normal position of vascular trunks with kidneys in place; b, their position when left kidney is delivered; c, their position when right kidney is delivered.

chored less firmly on the right side, and consequently it is pulled with greater ease toward the left than toward the right, while the vena cava permits a greater degree of lateral displacement on the right. The length of

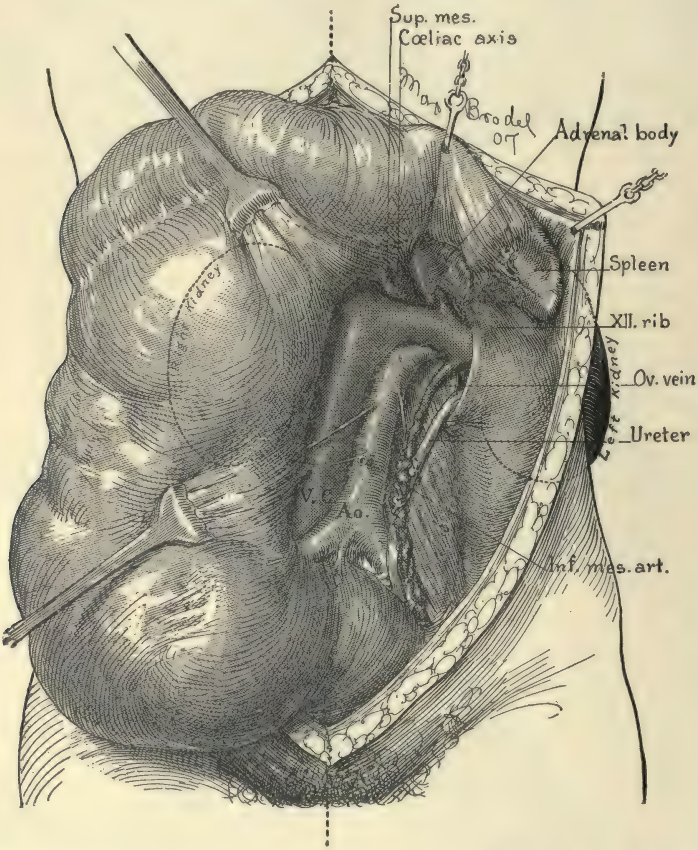


FIG. 181.—DISPLACEMENT TOWARD LEFT OF ABDOMINAL VENA CAVA AND AORTA WHEN LEFT KIDNEY IS DELIVERED THROUGH LUMBAR INCISION. The abdominal organs still covered with peritoneum have been drawn *en masse* toward the right side exposing great vascular trunks. Autopsy study.

the renal vessels, however, counterbalances the lack of mobility of the large vessels, i. e., that of the aorta to the right and that of the vena cava to the left, in so far as the renal vein on the left is much longer than on the right and the renal artery of greater length on the right than on the left. This complex relationship is perhaps better understood by studying Figures 181 and 182,

showing the same body in which on both sides lumbar incisions in the above-described manner had been made. The body was then opened by a median incision and the aorta and vena cava exposed in order to study the amount

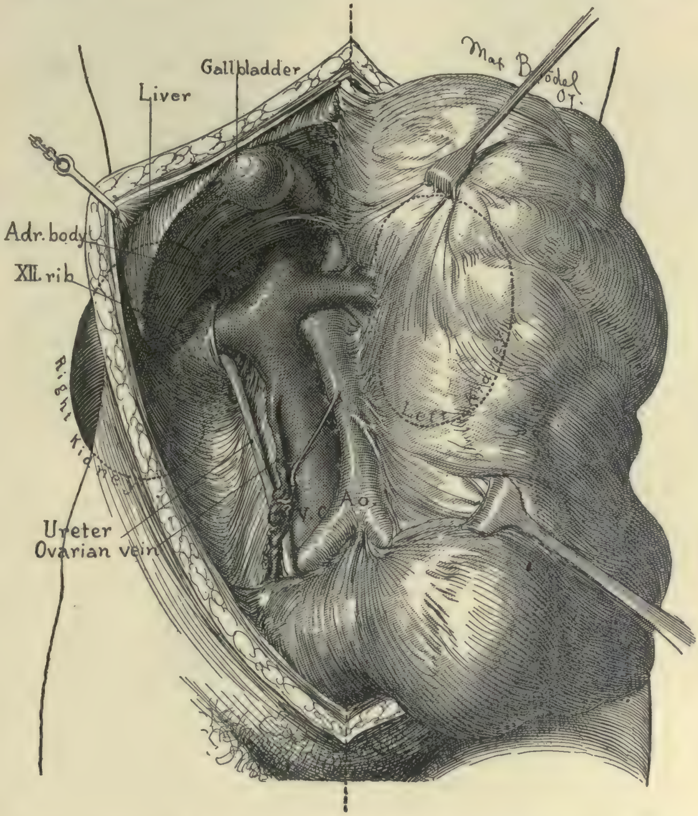


Fig. 182.—Displacement of Large Vascular Trunks by Delivery of Right Kidney through Lumbar Incision. Note shortness of renal vein on right side as compared with that on left. This renders danger of hemorrhage and injury to vena cava or the renal vein greater on this side than on the left. This is especially true when there are several separate renal veins.

of lateral displacement to which these large vascular trunks are subjected during the process of bringing the kidney out of the incisions.

As the attachment of the renal vessels to the aorta and vena cava is on a higher level than the highest point of a lumbar incision, the direction of the traction is downward as well as outward, and slightly more downward on the

left side, because the vascular pedicle of that kidney is usually situated somewhat higher up.

The amount of possible lateral displacement of the aorta and vena cava varies with the force of the pull to which the renal vessels are subjected, providing the aorta and vena cava possess their normal mobility. If, however, they are more firmly anchored to the vertebral column, the displacement may be very slight, even when a high degree of tension of the renal vessels exists. Such displacement and tension are least pronounced in cases of movable kidneys, where the renal pedicle is narrow and of considerable length, so that in some selected cases a kidney may be brought up into the wound without the slightest tension of its vessels and without a trace of lateral displacement of the large abdominal trunks. On the other hand, the tension on the renal vessels and the displacement of the great vascular trunks is greater when the renal vessels are short. A low degree of mobility of the aorta and vena cava associated with a short renal pedicle causes dangerous tension on the kidney vessels. The worst cases of this kind are those in which there is a short and broad pedicle, i. e., where two or more separate renal arteries are found, or several veins. It is obvious that there is danger of tearing one of several of such vessels, especially veins, in attempts to bring the kidney into view. The veins are injured much more easily than the arteries, and, owing to the short renal vein on the right side and to the fact that there is

Fig. 183.—Incision to Expose Kidney Where More Room is Necessary than Afforded by That Shown in Fig. 173. This is applicable to moderate-sized stone, to tubercular, and to pyonephrotic kidneys. Posture of patient on bag the same as in first incision.

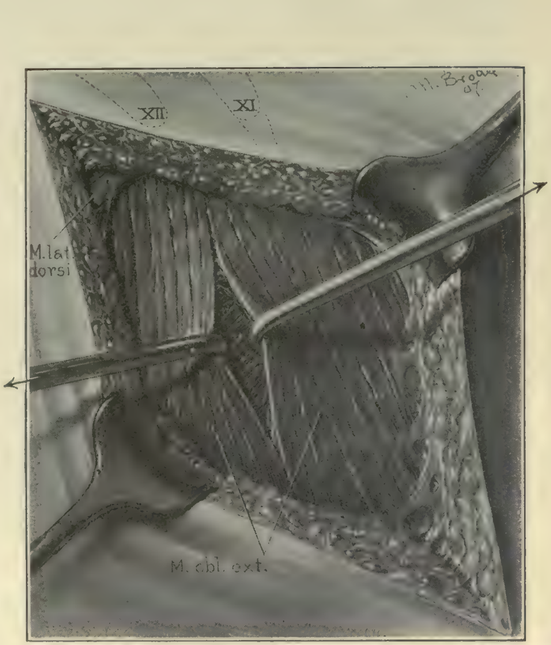


FIG. 184.—SECOND STEP IN INCISION SHOWN IN PRECEDING FIGURE. Note separation of fibers of the external oblique muscle.

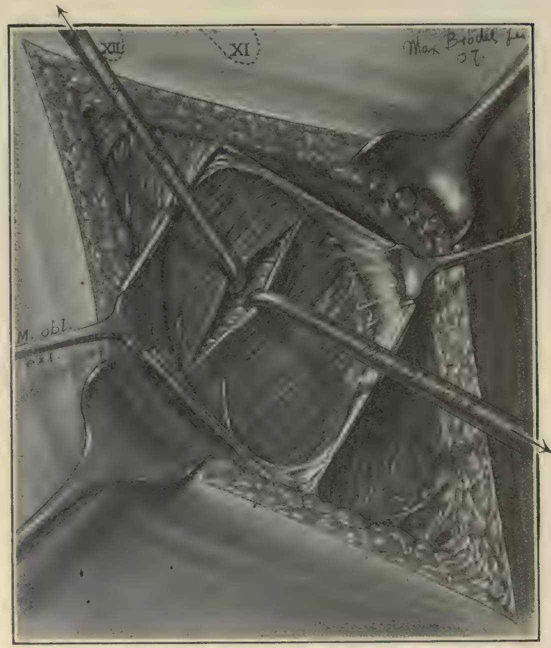


FIG. 185.—EXTERNAL OBLIQUE RETRACTED; INTERNAL OBLIQUE SPLIT IN DIRECTION OF FIBERS.

such a short distance to the opening for the vena cava in the diaphragm, an operator should be most cautious in dragging a kidney into view on the right side, especially if the palpating finger reveals the presence of more than one renal vein.

Figure 180 *b* and *c* shows in a semi-diagrammatic way what takes place during the process of bringing a kidney out of the lumbar incision. The other kidney always follows in the direction of the pull, but, as a rule, for only a short distance, the extent depending upon the length of its vessels and their elasticity.

The adrenal bodies remain more or less in their places, as the kidney has been freed from its capsule before bringing it out. They follow to some extent, however, because of their vascular attachment to the renal vessels, which is more intimate on the left side.

It is surprising what extensive procedures can be carried out through such an incision. If, however, in any case there is difficulty in the exposure and evidence of too much tension, extensions of this incision must be carried out. This is particularly important in cases where conservative procedures are intended. It has been the disagreeable experience of more than one operator to have to remove a kidney after tearing a renal vein while attempting the delivery of the organ.

Incision for Extensive Renal Operations through the Broad Abdominal Muscles, below and Lateral to the Superior Lumbar Trigonum.—For the exposure of enlarged pyonephrotic or tuberculous kidneys or those affected with malignant disease, the incision just described is insufficient.

There are several methods available to the operator, namely:

I. Enlarge the blunt opening in the superior lumbar triangle by cutting in a direction downward and forward through the oblique muscles. This incision is best made parallel to the iliac crest between the subcostal and I lumbar nerves and vessels, severing the lateral cutaneous branch of the subcostal (Fig. 183).

II. The second is a so-called gridiron incision through the broad abdominal muscles (similar to that described by Abbe and Mayo Robson). It is best to make it between the last thoracic and first lumbar nerves and vessels for reasons to be stated, and then, if this opening is not of sufficient size, it can be enlarged by means of an incision through the muscles up toward the center of the superior lumbar trigonum (see Fig. 190).

III. The necessary room may also be gained by resection of the XII, or of the XI and XII ribs.

The incision through the skin begins 3 cm. below and in front of the

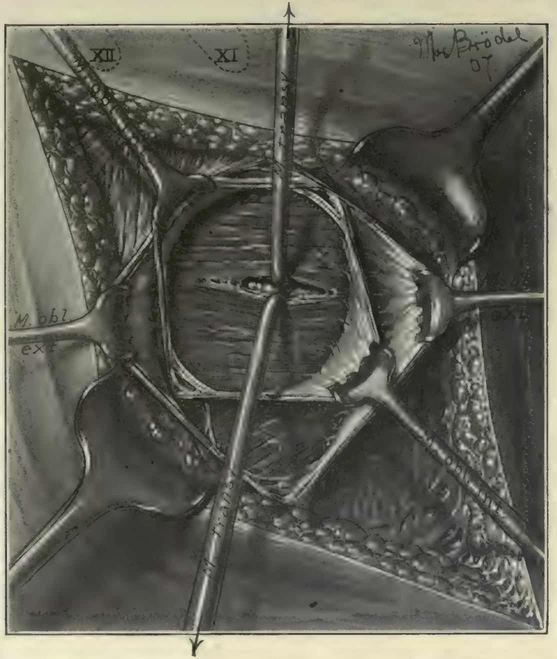


FIG. 186.—EXTERNAL AND INTERNAL OBLIQUE, RETRACTED; TRANSVERSALIS SPLIT IN THE DIRECTION OF ITS FIBERS.

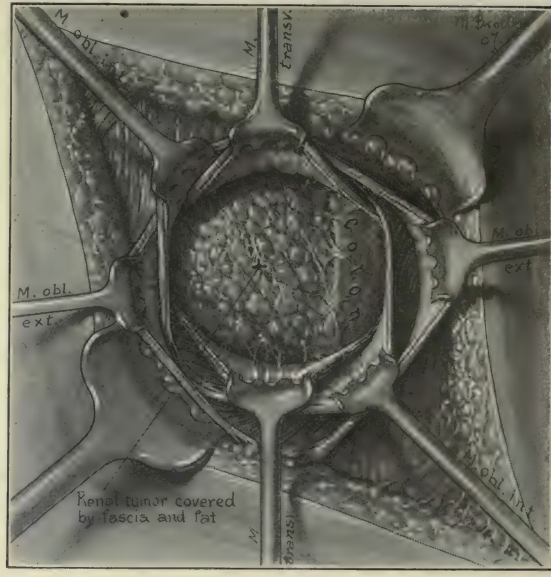


FIG. 187.—ALL THREE MUSCLES RETRACTED, SHOWING FAT LYING OVER RENAL TUMOR. Anterior to the fat is the peritoneal reflection of the colon. The line of this reflection varies considerably, depending on the individual as well as the size of the tumor. This incision may be greatly enlarged by pulling it open with the fingers of both hands, as shown in Figure 178

superior lumbar triangle and extends to a point 3 cm. above and either directly over or anterior to the anterior-superior spine of the ilium (Fig. 183).

The cut is carried through the skin, fat, and superficial fascia, and exposes the fibers of the external oblique (Fig. 184). The muscles of the lateral abdominal wall are then separated in the direction of their fibers, as in the

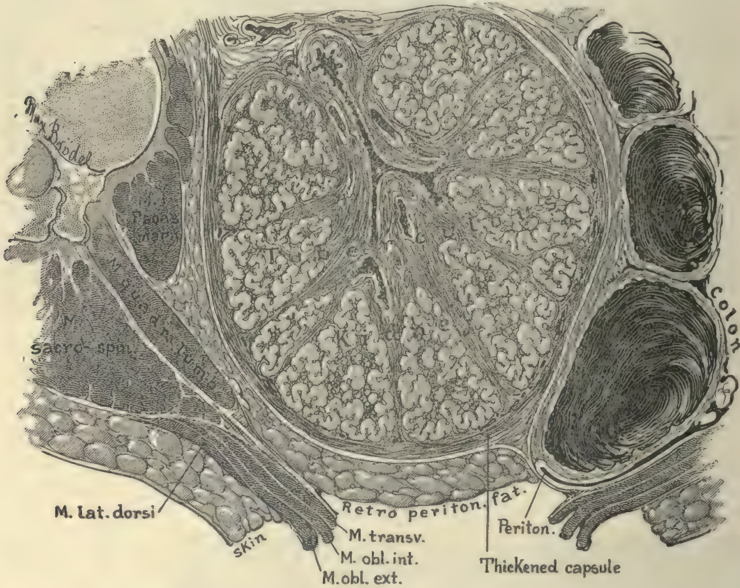


Fig. 188.—Transverse Section through the Body at Level of Incision Shown in Three Previous Drawings. Note the relations of surrounding structures to large tuberculous kidney. Ample exposure is necessary in such a case owing to the intimate attachment between the capsule of the kidney and the peritoneum. In separating these structures, the colon and, on the right side, the duodenum may be injured.

typical McBurney operation for appendicitis. The external oblique fibers are longest and should be separated in the lines between the anterior-superior spine of the ilium and the tip of the last rib. When separated the internal oblique comes into view (Fig. 184). Its fibers are longest and should be divided in a line from the 9th costal cartilage to the middle of the crest of the ilium. Two points on this line permit perforation of the muscles without injury to either nerves or vessels. One is just above the subcostal nerve and vessels, the other below them. It is well to remember that the vessels and nerves run beneath the muscles. The relations are shown in Figure 185. The separation of the fibers of the internal oblique exposes those of the transversalis, which are sepa-

FIG. 189.—T-SHAPED INCISION. This gives abundance of room and is suitable when a large tumor of the kidney is to be dealt with. The perpendicular arm follows the linear semilunaris; the transverse is approximately parallel to the last rib. The incisions are carried through all the layers of the abdomen down to the peritoneum.

rated, as shown in Figure 186. The fibers of the transversalis are of about equal length in all parts of the muscles. The relation of the vessels and nerves to this incision are shown in Figures 192 and 193. At the upper and outer

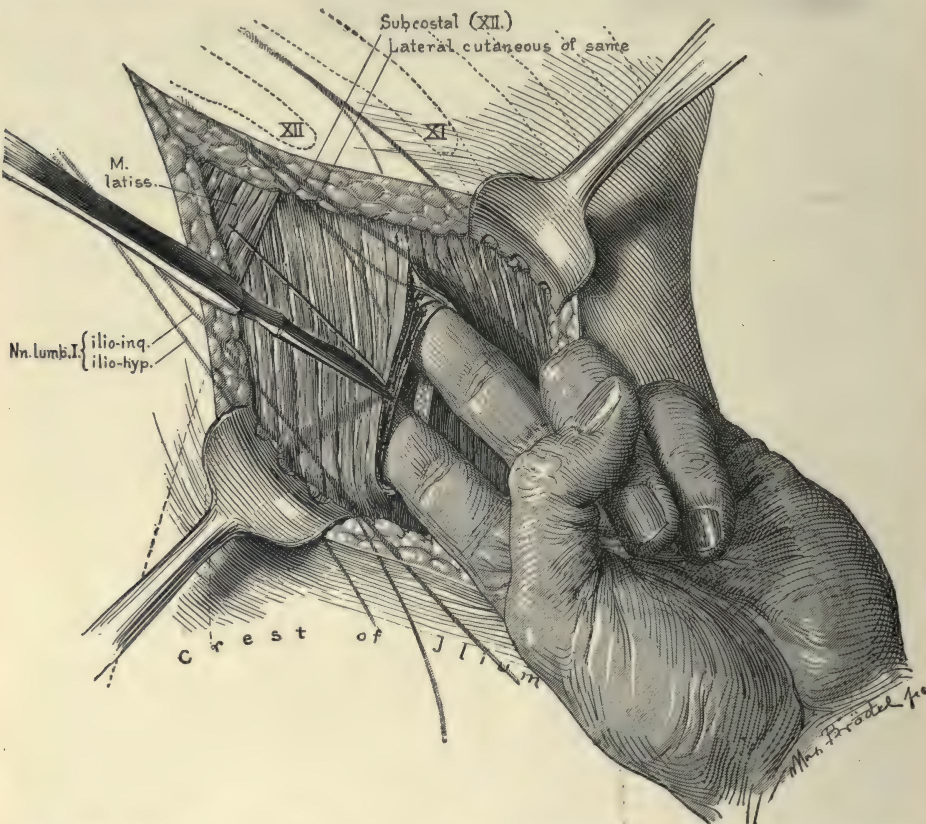


FIG. 190.—MUSCLE-SPLITTING INCISION SHOWN IN PRECEDING FIGURE. This may be greatly enlarged by upward incision across muscle, parallel to nerves, as shown. This makes the so-called frying-pan incision.

margin are the abdominal branches of the subcostal nerve and vessels, which lie between the internal oblique and transversalis. At the median margin are the lateral cutaneous branches of the same vessels and nerves running superficially. Below and medianly are the first lumbar nerves and vessels lying between the internal oblique and transversalis muscles. In the floor of this incision lies the renal mass surrounded by its fatty capsule, Gerota's capsule,

and the retrorenal or pararenal fat. In cases of marked inflammation it is not possible to distinguish the separate fatty layers; they may be fused into a homogeneous mass. Normally, however, the orange-colored pararenal fat pre-

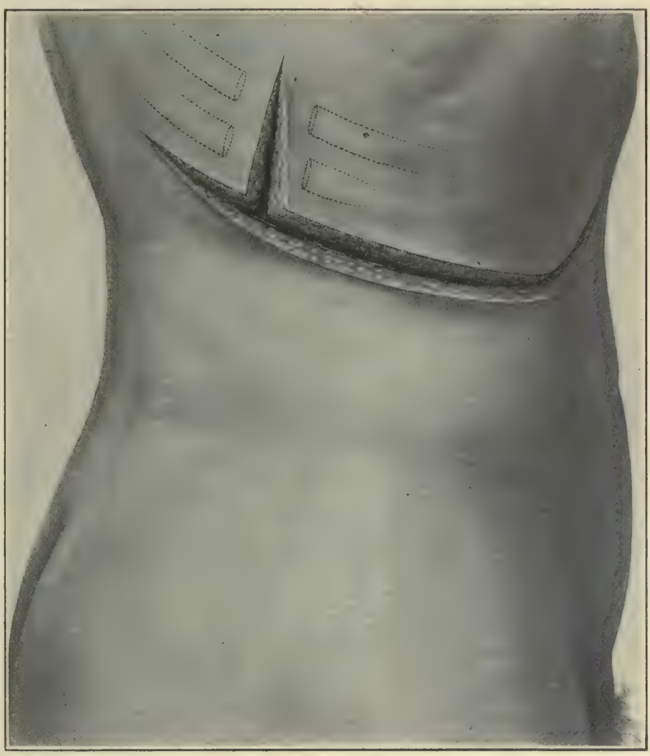


FIG. 191.—EXTENSIVE INCISION SUITABLE FOR OPERATIONS FOR TUMORS OF THE KIDNEY, ESPECIALLY THOSE WHICH ARE VERY VASCULAR OR ADHERENT AT THE UPPER POLE. The transverse incision begins over superior lumbar triangle and follows the thorax downward and forward to the anterior lateral border of the abdomen and then turns upward, following costal margin. The incision perpendicular to this is made in association with resection of pieces of eleventh and twelfth ribs. This is the so-called barn-door incision.

sents a very different appearance from the pale perirenal fat. In front is the reflection of the parietal peritoneum, over the colon (Fig. 187). This varies with the individual and also markedly with the size of the renal tumor. The relations of the kidney to the different layers of the abdominal wall and to the peritoneal organs are well shown in Figure 188, which shows a large tuberculous kidney as it appears in a transverse section of the body through the middle

of this incision. It is readily seen how serious injury may occur not only to the peritoneum, but to the abdominal organs, especially the duodenum on the right side, when there are dense adhesions between the kidney and these structures. Except in malignant disease where an exposure must be gained

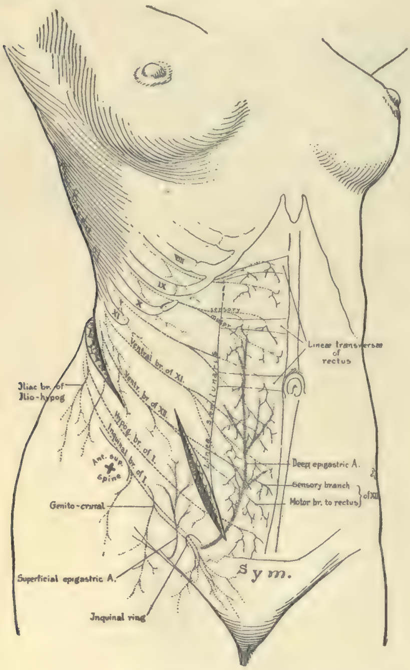


FIG. 192.—DIAGRAMMATIC REPRESENTATION OF INCISIONS FOR NEPHRO-URETERECTOMY. Note distribution of nerves and arteries. The lumbar incision is parallel to the nerve branches; the abdominal crosses the ventral branches, and cuts the last dorsal and first lumbar nerves. The former is for removal of kidney and upper ureter, the latter for removal of lower ureter down to bladder.

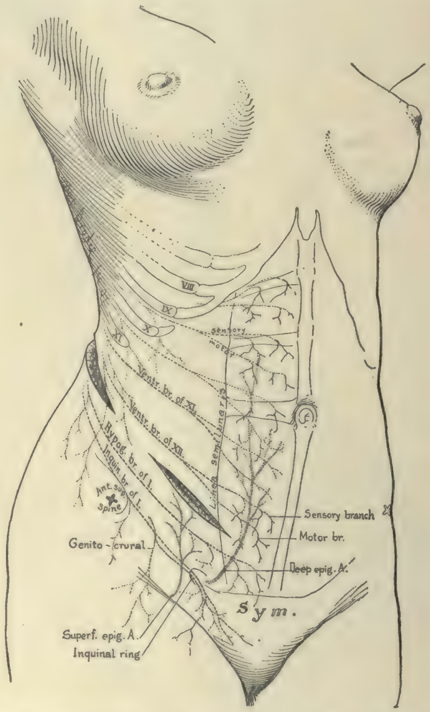


FIG. 193.—SAME AS PRECEDING FIGURE, EXCEPT THAT THE INCISION IS MADE SO THAT NO NERVES ARE SACRIFICED. The muscles may be cut directly through or, better, the fibers separated, as in McBurney incision.

which permits control of the entire situation by the eye, all such cases should be treated by intracapsular nephrectomy.

IV. In new growths of the kidney as well as in some other conditions it is essential to get at a renal pedicle *in situ*. To attain this let much wider incisions be made. One of the most useful in our experience is that here shown (Figs. 189 and 190). Incision is made as in last type. From the middle of

this incision a cut is made through the muscles parallel to the nerves up toward and into the superior lumbar triangle. Before making this incision through the muscles, the retractors should be removed and the fingers introduced into the wound, as shown in Figure 190. This enables the operator to determine the rib, the lateral border of the quadratus lumborum muscle, and to make a course which avoids the subcostal vessels and nerve as well as the first lumbar nerve. The only nerves injured are the lateral cutaneous branches of the subcostal. This incision is a very good one in that it affords large exposure and yet does but little injury to the abdominal wall, practically none to the nerves. The extension backward suggested the handle of a frying-pan and it is the custom with us to speak of it as "the frying-pan incision."

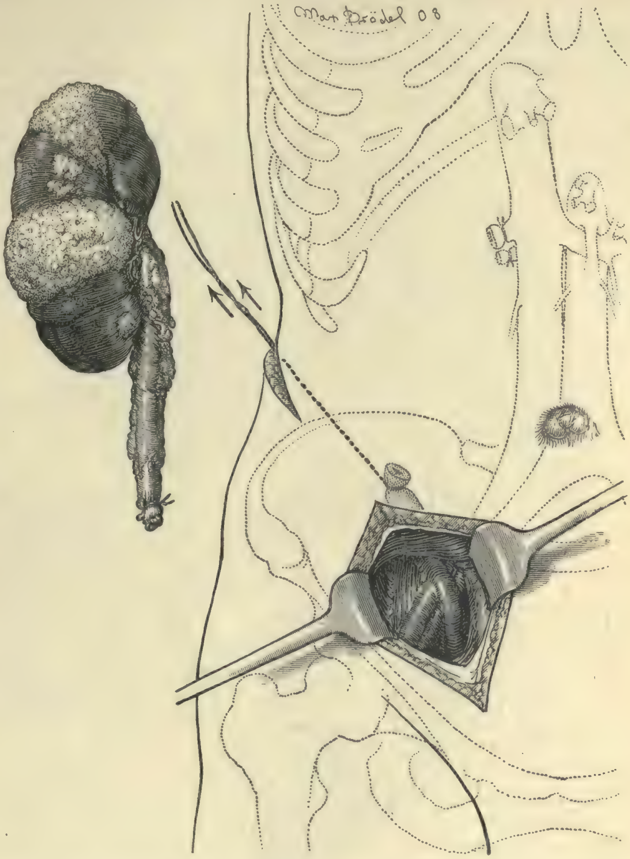


FIG. 194.—NEPHRO-URETERECTOMY. Kidney and upper ureter removed through lumbar incision. Cut and sterilized ureteral stump held by ligature passing out of lumbar incision. By gently pulling this, motion is transferred to the ureter and it can be more easily located in depths of ventral incision. When located, upper part of ureter is first dissected free and with its ligature drawn out of the incision in front. By blunt dissection the ureter can then be freed and removed all the way to the bladder.

Resection of the Ribs.—In patients with deep chests, even when there is not marked pathologic change in and about the kidney, there is often

great gain obtained in the way of exposure by the removal or the resection of parts of the last rib or of the last two ribs. In cases of laced thorax this is often a necessary procedure. The ribs should be removed sub-periosteally. The incision in the superior lumbar triangle is extended in the latissimus dorsi muscle and the serratus posticus inferior over the XII rib. The periosteum of the XII rib is split and enough of the rib is removed to gain the desired exposure. When the entire rib is to be removed the sacro-spinalis muscle must also be incised. This procedure causes no injury to vessels or nerves. The r e f l e c t i o n of the pleura should be observed and carefully avoided. If the pleura should be injured it can be safely and readily stitched.

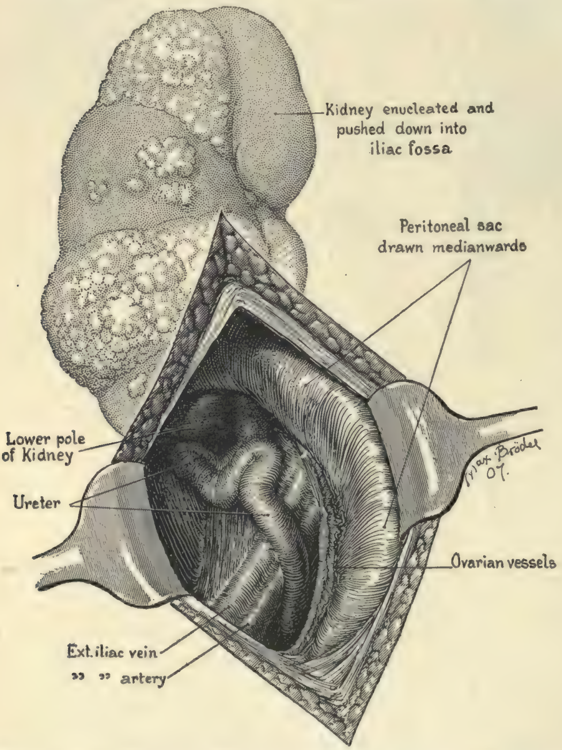


Fig. 195.—Pushing Down of Tubercular Kidney Freed from Its Vascular Pedicle from the Lumbar Incision to the Ventral Incision. This can be readily done and was carried out in earlier cases. It is now abandoned for the simpler and cleaner method shown in preceding figure.

V. An incision which gives magnificent exposure to the entire kidney, even in cases of very large tumor, is that shown in Figure 191. It begins over the superior lumbar triangle, skirts the margin of the ribs about an inch away from them, and passes forward parallel to the costal cartilage margin. This crescentic opening gives a wide exposure. In addition to this the last two or three ribs may be cut across near the superior lumbar triangle and the e n t i r e chest wall turned up. This incision, applicable to malignant tumors, has been entitled the barn-door incision. It does cut a good many nerves, muscles, and blood vessels, but, as we have demonstrated, heals promptly and with an apparent excellent restoration of function.

Incisions for Nephro-Ureterectomy.—We never find it necessary to employ the incision extending half-way around the body originally recommended by Israel. It is possible to do a complete nephro-ureterectomy through a small lumbar incision such as described in our first type, together with a second small incision in the lateral, anterior abdominal wall. The appearance of these two

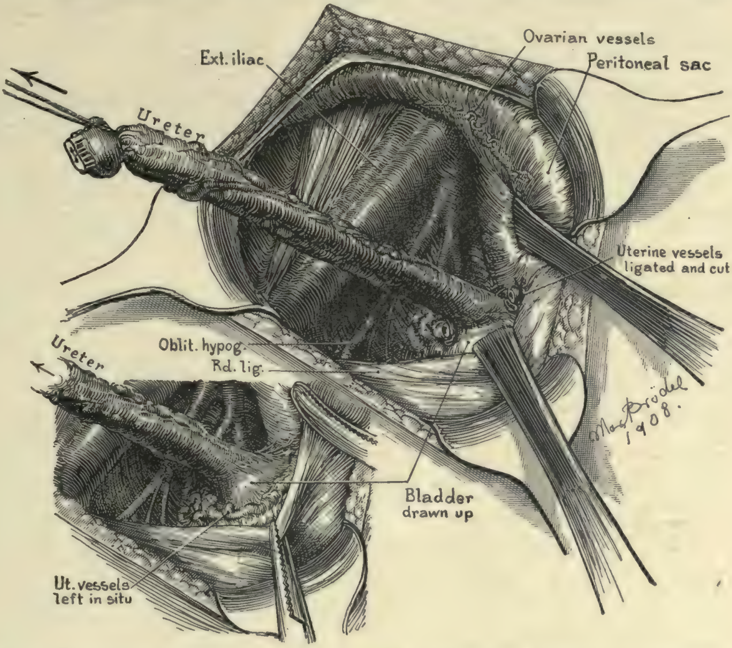


FIG. 196.—REMOVAL OF VESICAL END OF URETER THROUGH VENTRAL INCISION. The dissection is carried out bluntly down to the bladder. Even a cone of bladder around the corresponding orifice can be removed. The upper figure shows tied and severed uterine vessels, a procedure sometimes necessary to sufficient exposure. In the lower figure, uterine vessels have been rolled forward and preserved.

incisions is shown in Figures 192 and 193. The kidney is detached in the usual manner, the ureter freed as far down as possible, and then best cut and ligated, care being taken to sterilize the ends (Fig. 194). Originally one of us —Kelly—was in the habit of pushing the kidney down under the bridge of abdominal wall to the lower incision (Fig. 195). When the kidney is cut loose it is of advantage to have a ligature attached to the vesical end of the ureter to come out through the lumbar incision. The second incision can be made at the outer border of the rectus abdominalis muscle, as shown in Figure

192, or in an oblique direction parallel to the nerve trunks of the abdominal wall and to Poupart's ligament, as shown in Figure 193. This incision may be a muscle-splitting one, as in the McBurney. In the female it is sometimes necessary to ligàte the uterine vessels when they are reached, as shown in Figure 196. The entire ureter may be removed from above, as shown in Figure 196, or the vesical end may be removed through the vagina.

FURTHER CONSIDERATIONS IN REGARD TO THE ATTAINING OF SUFFICIENT EXPOSURES FOR OPERATIONS ON THE KIDNEY.

After the incision down to the kidney the operator must detach the perirenal fat, free the upper pole, free the lower pole, and deliver the kidney.

Opening the Fatty Capsule.—This is felt and opened by carrying the finger backward and inward into the mass of fat overlying the quadratus lumborum muscle. It is important to avoid the error of pushing the finger into the tissue in front of this and more anteriorly. If this is done the peritoneum is opened and the margin of the liver close by may be mistaken for the kidney, and even an experienced surgeon may begin to enucleate it. One can not well make the mistake of pushing the finger back onto the lumbar muscle. The fatty basket with its thin elastic cellular web which lies between the peritoneum in front and the quadratus lumborum behind contains the kidney. The index finger is easily pushed through the elastic fibrous veil (Gerota's capsule) and enters a large area full of loose fat in which the kidney is at once felt. This fibrous capsule can often be hooked up on the finger and drawn out of the incision for demonstration.

Two kinds of fat then appear, the golden retroperitoneal and the lemon-colored perirenal fat in marked contrast, separated by the thin septum (Fig. 179).

Freeing Body of the Kidney.—The next step is to free the body of the kidney, its dorsum, its anterior and posterior surfaces, and both its poles. This must be a deliberate act carefully done, never hurriedly and superficially because it seems so easy.

The fat is detached and the kidney set free, first by sweeping the finger over the dorsum and the posterior and anterior surface well down over its pelvis, then freeing the upper pole by a more careful, less rapid peeling movement of the tip of the finger. If resistance is encountered then act still more carefully and steadily, and, as far as possible, utilize the trained sense of touch

in following and sticking close to the rotundity of the kidney as the upper pole is disengaged on all sides.

In bad cases where there are strong inflammatory adhesions, or in a malignant case such as an advanced hypernephroma, this may constitute one of the most difficult parts of the operation. Indeed, the separation may be impossible when there is extensive involvement of the diaphragm and the under surface of the liver.

As a rule, however, by dint of following the outline or the contour of the kidney, sometimes, too, with rupture at the upper pole, leaving some of the diseased renal tissue behind, the upper pole is freed, and when traction is made the whole mass comes down and escapes with a considerable suction sound. The injury possible to the peritoneum of the colon or the duodenum can be readily appreciated by study of the anatomical relations shown in Figure 188.

This freeing of an attached upper pole may constitute the whole crux of the operation, but, this done, the difficulties are over and the delivery and the enucleation proceed without any more difficulty. With the fingers once inside the fatty capsule there is little danger to any of the adjacent organs or viscera, unless by breaking through the capsule again at some point where there is manifest disease, and the capsule once encountered the operator proceeds with extreme caution.

We had a frightful case of dense adhesions of the upper pole of a cancerous kidney, in which having reached, as we thought, the upper pole, we then tried to detach it; it separated and the large kidney mass rotated down and out of the incision, but with an alarming hemorrhage from the site of the adhesions. We could not locate any particular bleeding vessels in the diseased friable tissues up under the diaphragm, all efforts to check it by firm packs were in vain, and the patient practically died on the table, the greatest tragedy a surgeon can be called upon to witness. The post-mortem examination showed that the adherent upper pole of the kidney had become detached from the lower one and that the bleeding came from the upper renal vessels. Had we at once either clamped all the renal vessels broadly, or, in spite of the hemorrhage, persisted in enucleating the upper segment and bringing it down with the rest, the hemorrhage would have been controlled by the usual methods.

The lower pole of the kidney is separated from its fat in the same manner as the dorsum and its anterior and posterior faces; the only point of special interest is the ureter which skirts it. It is always of advantage to see this and know just where it lies, either by inspecting the fat to the median aspect of the lower pole in which it lies embedded or by tracing it down from the pelvis above.

The ureter should be treated with respect; it ought not to be dissected out unless it is to be removed or operated upon. Care must be taken, too, to avoid injuring its delicate vessels.

The kidney now being freed on all sides remains attached only by its vessels and its pelvis with its ureter.

If the work has been carefully done and the organ is not already diseased, it has not suffered the slightest harm from the manipulations necessary to set it free within its fatty capsule.

Delivery of the Kidney.—The next step is the delivery of the kidney out of the incision onto the surface of the body. The difficulties in the way of the delivery of the detached kidney from the incision onto the surface of the body may proceed from two sources: (1) the size of the kidney; (2) the vascular attachment at the hilum.

The Size of the Kidney.—A kidney which is not much enlarged can be delivered by judicious and careful traction from an incision of ordinary size, that is to say, one which is made through the superior lumbar triangle by pulling the tissues apart by blunt force, an incision just large enough to introduce four fingers or the whole hand (Fig. 173).

Again a large pus kidney or a hydronephrotic kidney which is to be removed can be opened and evacuated and so reduced in size and delivered collapsed through a small incision.

If the kidney is large, say as large as the fist, and cannot be reduced in size, then a larger incision must be made to deliver it, and this is done by separating the sides of the original triangle incision as widely as possible, and holding them in this position, cutting first through the skin and fat and then through the muscles in a direction downward and forward, adding a sort of handle two or three inches long to the first opening. Any kidney not more than 3 or 4 times the size of a normal organ can be removed through such an opening.

The two incisions described serve for all small and moderately enlarged organs. If the kidney is greatly enlarged, say the size of three or four fists, and is fixed in the upper abdomen under the vault of the diaphragm, then another type of incision is necessary for its exposure and removal, namely, an incision T-shaped with the horizontal bar extending from the superior lumbar triangle half way between the ribs and the crest of the ilium and the vertical bar extending up and down the semilunar line, similar to the frying-pan incision (Fig. 189).

Sometimes the kidney is greatly enlarged and immovable and the fixation is at the upper pole entirely out of sight and almost out of reach. Here it is

of the utmost importance to get at the affected part *in situ;* in other words, to make an incision of such a character that the covering tissues can be reflected upward until the adherent structures can be seen and handled carefully in the natural site.

This can be done by a curvilinear incision sweeping from the superior lumbar triangle out to the semilunar line and then up on this line toward the margin of the ribs. To this margin may be added a vertical incision posteriorly over the ribs which are resected (barn-door incision, Fig. 191).

TYPES OF KIDNEY OPERATIONS.

As mentioned at the very beginning of this chapter, operations on the kidney may be divided into several kinds.

First, to correct misplacements such as occur in movable kidney; here, too, should be placed operations which consist in the cutting of bands or removal of obstructions at the ureteral pelvic junction. As pointed out, operations of this class can be done, and best done, through the simple incision described and shown in Figures 173-176. The actual description of the further procedures in these operations is given in the chapters on Movable Kidney and Hydronephrosis. Under Hydronephrosis, too, are the details of the numerous plastic operations devised to secure free drainage through the ureter from the kidney to the bladder.

Second, those to open and drain pyonephroses and abscesses of the kidney. Operations of this kind can usually be carried out through the simple incision referred to for cases of the first type, as pointed out in the chapters on Pyonephrosis, Stone in the Kidney, Tuberculosis; this operation is usually a palliative one to tide over difficult conditions, such as extremely low condition of the patient. We will describe here briefly the typical method of doing nephrotomy in this class of case.

Third, those to carefully explore the entire kidney and pelvis. Such operations have their principal field in connection with stones in the kidney and, to a lesser extent, in cases of unexplained bleeding and infection. The successful and safe carrying out of these procedures depends on an accurate knowledge of the anatomy of the kidney, and will be discussed in full in the next chapter.

Fourth, those which have as an end the removal of the kidney, a condition which must be met in a great variety of conditions, and, as already explained under Incisions, depending on the nature of the disease. There are certain

general principles which underlie all of these procedures, and which for that reason are recounted here.

Nephrotomy for Large Pus Kidneys.—The indications for nephrotomy in pus kidneys are given in detail in the chapters on Infections of the Kidney, Tuberculosis of the Kidney, and Stone in the Kidney. The operation is usually a very short one. The incision should be made, as a rule, in the superior lumbar triangle in the manner already described. On getting down to the kidney surrounded by its adherent fatty capsule it is usually of advantage to aspirate the sac, as shown in Figure 401. After emptying the pus the opening can be made with a blunt clamp and then with the fingers. The pus should be evacuated, separate loculi should be broken into, and the incision drained with a rubber tube surrounded with gauze. This is the first procedure to be carried out in Intracapsular Nephrectomy, when done either at one sitting or in a two-stage operation. (Figures 402, 403 and 404.)

Nephrectomy.—The removal of the kidney in general is the largest and most aggressive operation that the surgeon can perform in urological work. The technique of the operation varies considerably according to different conditions. Hemostasis is with either ligatures or secured clamps, and with the kidney drawn down and outside the wound or more or less *in situ.* We think it best to use the clamps only in case of necessity—where it is difficult to reach the vessels so as to apply ligatures, or where the vessels are infiltrated and so can not be distinguished in the hilum, or where there is a sudden hemorrhage due to a vessel tearing or slipping. In such cases a strong clamp (see Fig. 296) can be applied and left on the renal vessels from 48 to 72 hours. As said before, however, the clamps should only be applied in urgent cases and never as a matter of choice. Ten years ago it was our practice to leave the clamps on in very difficult cases. It is several years since this procedure has been resorted to; the difficulty is that it is impossible to be sure that the clamps can be removed with safety after 72 hours. A distinguished colleague has personally communicated a case where instantaneous death from hemorrhage followed the removal of the clamps even after an application of several days.

The removal of the kidney will vary according to the disease and also according to its extent. The most extensive removal is carried out where there is malignant disease. In such cases the kidney, the entire fatty capsule, and Gerota's capsule are removed. The next most extensive removal is where the kidney is exsected with its true fibrous capsule. This is the typical nephrectomy. A third procedure, often employed with great advantage in pus and tubercular kidneys, is the removal of the kidney alone, leaving in the fibrous capsule.

In each of these procedures, the parts to be removed must be separated from surrounding parts before the ligation of the blood vessels is begun, and thoroughly mobilized.

How to Take the Kidney Out, when It Is Delivered from the Wound.—In doing a nephrectomy with the kidney delivered from the wound the operator first assures himself that the kidney is freed on all sides except at its hilum and pelvic attachment to the ureter. The vessels are generally obscured by more or less fat. By taking a blunt instrument or a crenated spatula the fat is pushed back carefully until the vessels are more or less satisfactorily exposed. If the fat is adherent the operator will then do well to content himself by holding the tissues containing the vessels between the thumb and forefinger and feeling definitely the pulsations of the arteries. He then passes a catgut ligature by means of an aneurysmal or other blunt needle through the upper part of the hilum embracing about 1 cm. of the tissue and as far away from the kidney as convenient. Then releasing the pull on the kidney so as to make the vessels slack, the ligature is tied very tight (Figs. 293 and 294). Then, clamping the vessels in the upper part of the hilum with a strong clamp next to the kidney, the tissues controlled by the ligatures are divided. Before reaching the limit of the zone thus controlled another ligature is applied, controlling another site of the tissue next beyond. Again the clamp is applied next to the kidney and the vessels divided between. In this way, with extreme caution, step by step, each ligature overlapping the territory of the preceding one, the vessels are all tied and severed at a sufficient distance from the kidney and with sufficient tissue distal to the ligature to insure against all risk of post-operative hemorrhage. Sometimes the ligature penetrates a vein and there is momentary, profuse, and alarming hemorrhage. This ceases, however, when the ligature is tied, and is always perfectly controlled when the next ligature is applied. During the last steps of the division, while the kidney still adheres by only a few strands or by one or two vessels, particular care must be taken not to put enough traction on these vessels to tear them. If there is any such possibility it will be best to apply a strong clamp well beyond the point at which the ligature is to be applied, and only to release it when the ligature is firmly seated and the tissue all divided. It is well to leave these ligatures alone until all have been applied and the kidney completely divided from its vascular system. It is safe to make gentle traction upon the ligatures sufficient to keep the vascular area in perfect view until the surgeon is sure that there can be no hemorrhage. Should any sudden or unexpected hemorrhage take place it is best to apply forceps at once deep into the tissues, grasping them until the bleeding is controlled. There is little use in trying to swab away the blood to

get a view of any considerable size, as the blood wells up so fast that it obscures the field.

If the severance of the kidney from its vessels has been carefully and successfully done, the pelvis has not been opened and the kidney still remains attached by its ureter. The operator now determines whether the wall of the upper part of the ureter is to be removed with the kidney, or whether, the ureter being normal, he will cut it off close to the kidney, or, whether, following Israel's plan, he will bring the ureter to the lower angle of the wound, attaching it to the skin for irrigation or subsequent treatment. The ureter may be clamped with two clamps and divided with a cautery, when the kidney is completely removed from the body. In infected cases it is important to avoid opening the pelvis or permitting any of its contents to escape over the wound. In such cases the ureteral end should be sterilized and turned in, and dropped, or the end of the ureter should be sewed into the angle.

In many cases where the upper pole of the kidney is harder to get at from adhesions or from the shape of the organ, a reversal of this procedure just described is of great advantage. In such a case the operation begins by severance of the ureter near its pelvic junction. The two ends are ligated and sterilized. The pedicle is then tied off in the manner just described except that the operator goes from below up. This procedure is shown in Figure 295.

Intracapsular Enucleation of the Kidney.—When a badly inflamed, suppurating tubercular kidney is embedded and fixed in the fatty tissues, the dangers of enucleation of the entire organ are greatly enhanced. The risk of tearing open the peritoneum, of wounding the colon or the duodenum, and of tearing the large renal vessels is a serious one. In such cases it is often possible to do an intracapsular enucleation; that is, to remove the kidney out of its capsule rapidly, safely, and in a perfectly satisfactory manner. Even tubercular kidneys treated in this way heal up as though the capsule had been removed too. There is, therefore, no valid objection to the operation, and for simplicity and safety there is everything to recommend it.

The general principles of this important procedure, shown in Figures 401-404, are as follows: In the first place, as little dissection as possible is done in the surrounding tissues.

The operator's first objective point is to penetrate the dorsum of the kidney through into the dilated calices and pelvis. This is followed by a thorough evacuation of whatever fluids may be contained in the organ, if necessary flushing it out freely, then using one or two fingers as an instrument, the renal substance is torn through from within outward as far as the capsule, which is felt as a firm resisting plane. As soon as this is reached, it is easy to

run the fingers up and down and in front and behind and strip the collapsing renal tissue loose from its capsule. The kidney, detached in this way, drops crumpled up toward this center. After sweeping the finger around on all sides, to make sure that it has been detached in every direction from the smooth, encasing walls of the capsule, the flaccid kidney is drawn out of the incision, or the incision is made large enough for it to be readily exposed, without too much traction. The kidney now lies in the grasp of the operator, attached by its base within the capsule, like the corolla of a flower within the calyx. The operator may now pursue one of two courses: He may cut through the pelvis of the kidney for a little distance from the margin of the organ and so expose and reach the renal vessels, which he then ties off. If this is difficult to do, he may catch the vessels just where they enter the renal substance, tying some of the ligatures through the renal tissues in an orderly direction from above downward or vice versa. If this is awkward, he can crush down on the renal tissues with strong forceps and then free out the tissues above, crushing until the resected vessels are exposed and ligated in small groups. By this method the vessels are tied well away from the hilum of the kidney in case of necessity. If there is any bleeding, the vessel is easily cut by passing a ligature over it with a round needle. The control of hemorrhage from the renal vessels treated in this way is always easy, and the operator feels a great sense of security as he deals with the kidney inside the well-defined, firm-walled capsule.

CLOSING THE WOUND AND AFTER-TREATMENT.

Closing the Abdominal Incision.—The opening at the superior lumbar triangle is best closed by two or three figure-of-eight sutures of catgut, drawing the external and internal oblique muscles over to the quadratus, to which they are firmly united, separating the membranous expanse of the triangle. Care must be taken in doing the suturing not to include and puncture the ilio-inguinal and hypogastric nerves, found skirting under the margin of the quadratus. When the muscles of the abdominal wall have been cut, it is always easy, if the work has been carefully done, to distinguish them and to sew the internal oblique and external oblique together layer by layer in their proper order. After the cut muscles are thus united, the opening which was first made at the site of the superior lumbar triangle is closed, as just described. It is best always to use catgut for these buried sutures. If the wound for exposure of the kidney is a very large one, and the patient in bad condition, then silkworm gut sutures ought to be passed through all the tissues, including the skin,

at intervals of about an inch. In this way a large wound can be closed very rapidly and the result, as a rule, is perfect, even if no superficial sutures are applied between them. In the ordinary incision when the deep wound is closed the skin wound may then be closed with a continuous subcuticular silver wire or with a horsehair suture.

Dressing.—The best dressing is a lot of soft handkerchiefs of dry gauze applied over the wound and held in place by adhesive straps and an abdominal binder. Unless there is some discomfort or elevation of the temperature these need not be touched until a week has elapsed.

Drainage.—The subject of drainage is of utmost importance in connection with the after-history of the case. It is our general rule never to drain any of the cases of suspension of the kidney, but to close the wound throughout in the manner just described, and, as a general rule, to drain every case in which any cutting operation has been done upon the kidney or its pelvis. If the operation is a small one and the wound has been well closed, and there is every reason to expect a prompt union without any discharge of fluids, then a cigarette drain consisting of a piece of iodoform gauze loosely wrapped up in protective rubber tissue may be slipped into the wound and left there tentatively, being pulled out in one or two days, or as soon as it is evident that there is going to be no discharge or that the discharge has ceased. In larger and more aggressive operations upon the kidney, as well as in cases of nephrectomy, it is a good plan to wrap up a piece of rubber tubing loosely in iodoform gauze and to wrap this again in protective and insert a drain the size of the index finger well up into the wound. Sometimes we use a mushroom catheter for the central rubber drain, which answers the purpose admirably. This should be watched, being left undisturbed as long as there is a free discharge. As soon as the discharge slackens, in one or two days, the drain should be started down by making a simple traction upon it so as to pull it out for one or two inches, then cutting it off. This is done every day until it is delivered entirely, when a little drain is slipped into its place. In suppurating and tubercular cases one must take care not to let the skin and muscular part of the incision close too quickly, bottling up a discharge above. If this occurs the patient should have a little gas as she lies upon her bed, when, with the index finger or a uterine dilator, the wound can be readily enlarged and explored and another larger drain put in. Sometimes in these suppurating cases a wound takes two or three months to heal up entirely from the bottom, and it is important to warn the patient of this fact that she may not be disappointed at the outcome.

After-Treatment.—The after-treatment of most renal surgical cases consists

in keeping the patient at rest, as free from pain as possible, and seeing that the kidneys are doing their work, and the bowels not inactive.

Posture.—The patient, as a rule, lies on her back. If there is a large draining opening she may lie tilted a little to that side to favor the escape of the discharge.

Sedatives.—There is no harm in giving a little morphia at first to quiet pain, but after the first 24 hours codein should be used preferably as a sedative. This can often be given in the form of a suppository with trional (codein gr. ss., trional gr. xv) to great advantage.

Liquids.—The patient may take liquid food in general as soon as the stomach will retain it, and the more pure water she can take the better. The urine ought to be carefully watched, both as to the amount and presence of albumin and gas. If one kidney has been removed, the secretion of the remaining kidney is naturally followed with unusual interest and sometimes with no little anxiety. It is common to notice a marked diminishing in the renal secretions from the opposite side, and for one or two days, especially where there is much vomiting, it is well to keep the bowels freely opened by giving mild salines.

We think that there is no special advantage in any particular form of diet, provided it is simple and nutritious, though it is better not to give much red meat while the patient is lying in bed. The ordinary time for rest in bed after a kidney operation depends in a large measure on the previous condition of the patient and the more or less aggressive nature of the operation. After a simple one two weeks is long enough, while a patient who has had a large renal tumor removed will have to remain there three. As soon, however, as she is able to do so, she would do better if put in a rolling chair and taken out on a porch to enjoy the sunlight and fresh breezes.

After-Care.—All patients who have had renal operations ought to report once or twice a year for further watching and urinary examination. Unfortunately here, as in other branches of surgery, when a patient passes out of the immediate care of the surgeon after an operation, she is apt to forget the necessity of remaining more or less under observation. It is always important that those who have had serious renal operations should avoid undue exposure to cold, sitting in draughts, great fatigue, or excesses at the table. They should in general live abstemious, regular, sensible lives, keeping as much as possible in the open air and keeping the emunctories in order, especially the skin and bowels.

CHAPTER XV.

THE SURGICAL ANATOMY OF THE KIDNEY, WITH ESPECIAL REFERENCE TO NEPHROTOMY AND RESECTIONS.

The ideal opening of the pelvis of the kidney should render accessible to examination all of its calices and pockets, at the same time it should cut as few blood vessels and do as little injury to the parenchyma as possible. The ideal closure of such a wound would be the bringing together in accurate apposition of the cut surfaces without either tearing or strangulating the kidney parenchyma. The indispensable guide to the attainment of such an incision lies in an understanding of the anatomy of the kidney and particularly of the distribution of its blood vessels. No one form of incision will meet all cases. While it is not possible in an individual case to tell with absolute accuracy the distribution of calices and vessels, nevertheless there are many surface markings which enable the operator to determine these questions clearly enough for practical purposes. The shape and position of the kidney, the relations of the hilum to it, the position and distribution of the blood vessels at the hilum are the points which yield the key to the situation.

THE PELVIS OF THE KIDNEY.

From a surgical standpoint all forms of pelves may be classified under two main groups:

(1) Single pelves with major and minor calices.

(2) Divided pelves, where there is no free communication possible between all of the calices inside of the kidney.

Single Pelves.—Figure 99 shows the ideal form of a true pelvis. There are 8 calices; the cranial and caudal calyx may have composite papillæ. The remaining six stand upon the pelvis in a double row, an anterior irregularly arranged, and a posterior, more regular row.

The horizontal axis of the pelvis (Fig. 99) runs from the posterior surface of the kidney obliquely through the organ to the outer third of its anterior surface, and the two rows of calices leave this axis at almost equal angles. The

posterior calices, therefore, point to a line just posterior to the lateral convex border of the kidney, while the anterior calices are directed straight forward into the convex anterior region of the organ.

The variations of this type were described on page 142. They do not materially affect the proposed method of splitting the kidney.

Divided Pelves.—While a thorough exposure of the interior of a single pelvis together with all its pockets is comparatively simple, the exposure may be very difficult or even impossible in divided pelves. Figures 84, 85, 203 and 224 show the various forms of divided pelves. Comparing them with the single type, note that between the upper and lower group of calices there is a zone of cortical substance which extends to the hilum. If there are three divisions, the deep cortical columns are two in number.

THE ARTERIES.

The renal artery lies higher than the vein and passes behind the vena cava on the right and behind the renal vein on the left. While the right artery may arise somewhat lower than the left, the conditions are more frequently reversed; in many cases, however, both arteries come off at the same level (45 per cent., Helm). The renal artery is about 7 mm. thick, of varying length, but usually longer on the right side, and divides either outside, or just at the entrance, or inside the kidney into four or five branches. The most frequent arrangement is that it divides first into two branches from 3-5 mm. in thickness, which again divide into several branches of a diameter of 2-4 mm. At their entrance into the hilum the arteries lie peripheral to the veins and remain so throughout their course. The arteries are end-arteries in the strictest sense of the word, and an artery that runs anteriorly to the pelvis stays anterior until the capsule is reached. In an arterial corrosion preparation the two trees of vessels can be separated and bent away from one another without injury to the fine branches in the cortex. The division of the artery in relation to the pelvis is usually such that three-fourths of the blood is distributed anteriorly, while one-fourth only is carried posteriorly. Occasionally the proportion is four-fifths to one-fifth, in which case there is a more marked overlapping of the anterior tree at the upper and lower pole of the kidney. On the other hand, both systems may be equally large or the posterior may be the larger. Concerning these variations more will be said later on.

If the pelvis of the kidney is found at the posterior surface of the hilum it is safe to say that three-fourths or four-fifths of the vessels run anteriorly

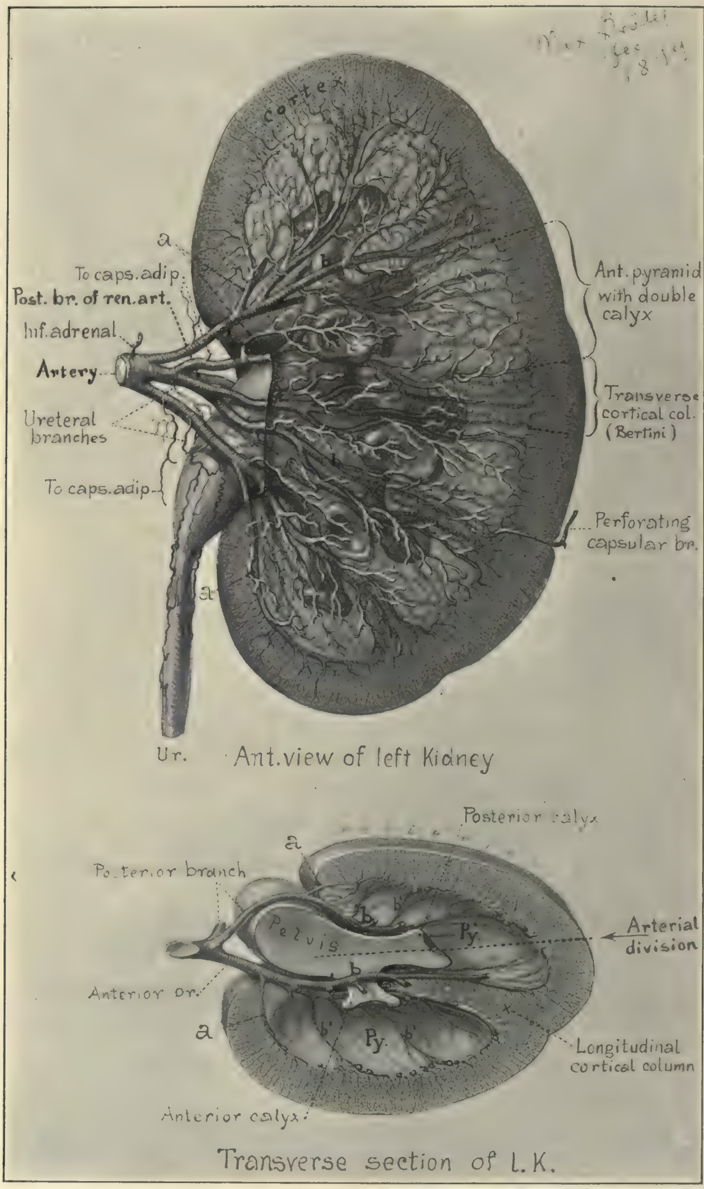


FIG. 197.—CORROSION OF ARTERIAL SYSTEM AND ITS RELATION TO RENAL PELVIS IN MOST FREQUENT TYPE OF KIDNEY.

and that the line of division of the arterial trees on the surface of the kidney is found in a definite position, viz., from ½-1 cm. posterior, and nearly parallel to the lateral convex border.

The main branches of the artery soon divide again into many small branches which have a diameter of 1-2 mm. and which radiate from the hilum in the shape of a fan, running in bundles between the calices to the sides of the

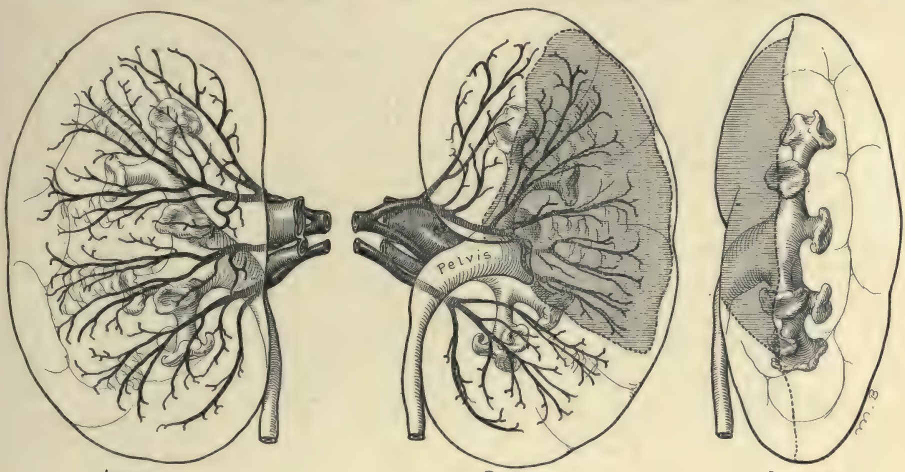


FIG. 198.—THREE VIEWS OF CORROSION PREPARATION SHOWING ARTERIAL CIRCULATION OF KIDNEY WITH EXCESSIVE ROTATION. The hilum is far posterior. Shaded area represents part of kidney supplied by small posterior artery. Note line of arterial division on lateral view.

pyramids until they reach their base. Between every two calices are one or two arteries which divide again into two or more branches. These branches are in the deepest portion of the columns of Bertin.

The branches around the pyramids are of two varieties:

(1) Those that hug the pelvis closely, with only the veins intervening (Fig. 197, b).

(2) Those that reach the base of the pyramid directly through the cortex without having come in the vicinity of the calices (a). These branches are seen along the hilum from the upper to the lower pole of the kidney. Their anatomical character is similar to that of a supernumerary artery, except that they arise from a large branch of the renal artery close to the hilum. They penetrate the cortex until they reach the middle of the base of a pyramid, where they break up into a network of small vessels. There are, as a rule, two

or three of these branches on each side of the kidney. They have a diameter of about 1 to $1\frac{1}{2}$ mm. and may be as long as 3 cm. The lateral border of the kidney is devoid of them, and only vessels coming from the calices are found at the base of the pyramids.

Corrosion preparations often show marked constrictions of the larger arteries at their points of origin, an arrangement which frequently causes diminution of blood pressure inside the kidney.

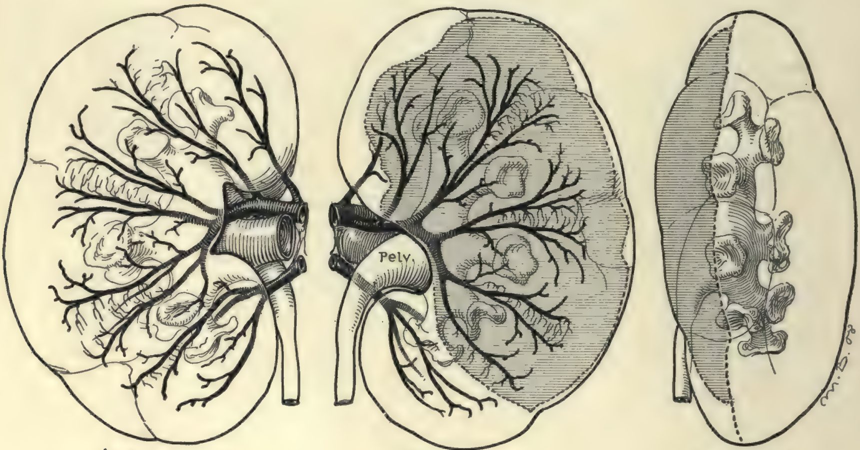


FIG. 199.—THREE VIEWS OF CORROSION PREPARATION SHOWING ARTERIAL CIRCULATION OF MOST FREQUENT TYPE OF KIDNEY. Shaded area represents distribution of posterior branch.

Figure 197 is a semi-schematic representation of the arterial blood supply of the kidney, as found in the majority of cases.

The pelvis is seen at the posterior side of the hilum. The anterior calices are short, the posterior calices long and pointing toward the lateral border. The artery sends the majority of its branches anteriorly and only one branch posteriorly. The arteries (b) are seen running close to the pelvis and calices up to the region of the papillæ, where they send off fan-like branches around the pyramids (b′). At a are the vessels that reach the base of the pyramid in the shortest way, i. e., they plunge through the cortex. The anterior branch supplies the whole of the anterior pyramid and the anterior portion of the posterior pyramid, while the posterior branch supplies only the remaining portion of the posterior pyramid. The arrow indicates the division between the vascular trees. This posterior branch is, from the surgical viewpoint, of the

utmost importance: (1) because of the regularity of its course (Figs. 198 and 199, 200 and 201); (2) it terminates over and parallel with the lower posterior calyx, thus permitting an easy and bloodless exploration of the lower pelvic division; (3) it furnishes the key to the determination of the plane of arterial division on the dorso-lateral region of the kidney and for the subsequent incision exposing the entire pelvis (Fig. 213).

The arrangement of the arteries at the upper and lower pole of the kidney

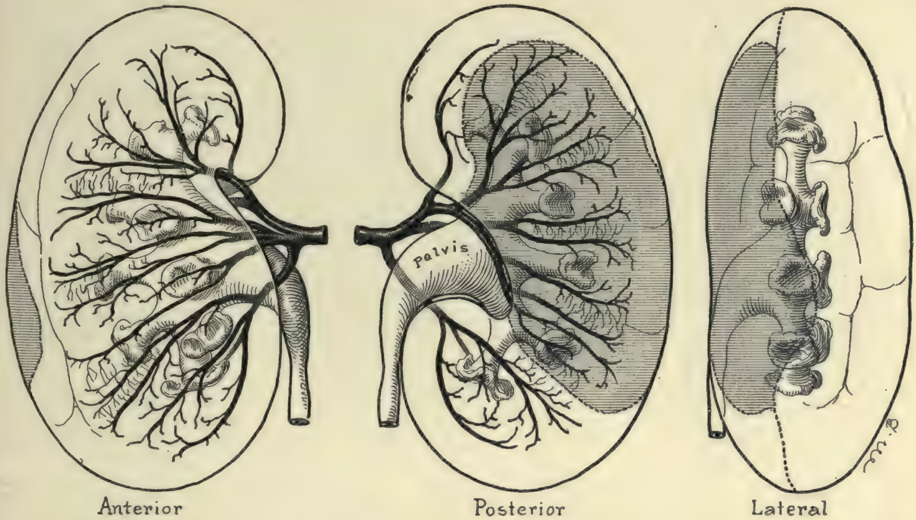


Fig. 200.—Three Views of Corrosion Preparation Showing Arterial Circulation of Kidney Similar to That Preceding, but with Addition of Spiral Twist. Compare with Figure 199. Shaded area shows distribution of posterior branch. Note how twist has caused line of arterial cleavage to overlap in anterior territory.

is quite characteristic. They are derived from the anterior group of vessels and run as a single trunk 3-4 mm. in diameter, or divided toward the base of the major calyx. The division is usually into three branches, the middle one of which makes a long sweep around the inner border of the pole (Fig. 197). However, it may also be quite short, in which case the other two take its place. The middle branch is the one that generally plays the rôle of the supernumerary artery which arises from the aorta and runs to the inner surface of one of the poles of the kidney (Fig. 203).

The upper and lower calices always remain between the corresponding anterior and posterior pole or branches, which, although they are derived from

the anterior group of vessels, divide and remain so in the prolongation of the non-vascular plane which exists in the middle of the kidney.

At the base of the pyramids the arteries bend in a gentle curve toward each other, whereby they still divide until the entire base of the pyramids is covered. They never anastomose, but when they seem to touch they bend away from one another and send their glomeruli-bearing branches to the surface. The large branches, as a and b, divide the base of the pyramid into sections.

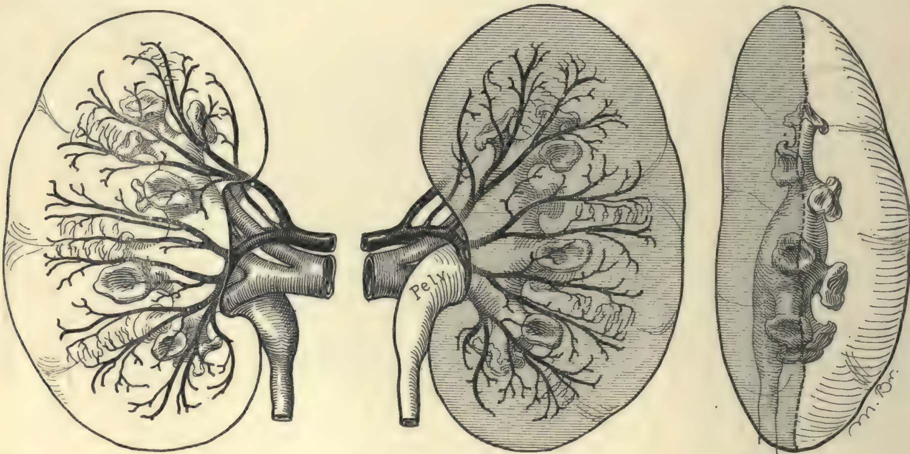


FIG. 201.—THREE VIEWS OF CORROSION PREPARATION SHOWING SYMMETRICAL ARRANGEMENT OF ARTERIAL SYSTEM. Compare with Figure 198. Note how shaded territory supplied by posterior artery equals one-half of kidney.

They run with their accompanying veins (which lie nearer the pyramid) in furrows as deep as 5-8 mm. or more, and give the base of the pyramid a peculiar lobulated appearance, which may lead to the belief that the sections are individual pyramids until the papillæ and calyx toward which they point are examined (Fig. 197).

The further course of the arteries, upward in the arteriæ interlobularis, downward in the arteriolæ rectæ, has been described in another place (p. 160).

Of course, the scheme of arterial circulation just described is applicable only to kidneys with posterior pelvis of the single type. Now to briefly consider the various deviations from this form:

It is fortunate that, while the arrangement of the arteries at the hilum may vary much, the location of the plane of arterial division on the lateral border remains approximately the same. Figures 199, 200, 201 and 202 are

diagrams of the lateral views of corrosion preparations, showing the remarkable similarity of the line in the great majority of cases. The figures speak for themselves.

As shown on page 134, the location of this line depends upon the degree of rotation of the kidney in relation to the arterial source. It was stated that:

(1) In cases of anterior pelves the posterior arteries preponderate and

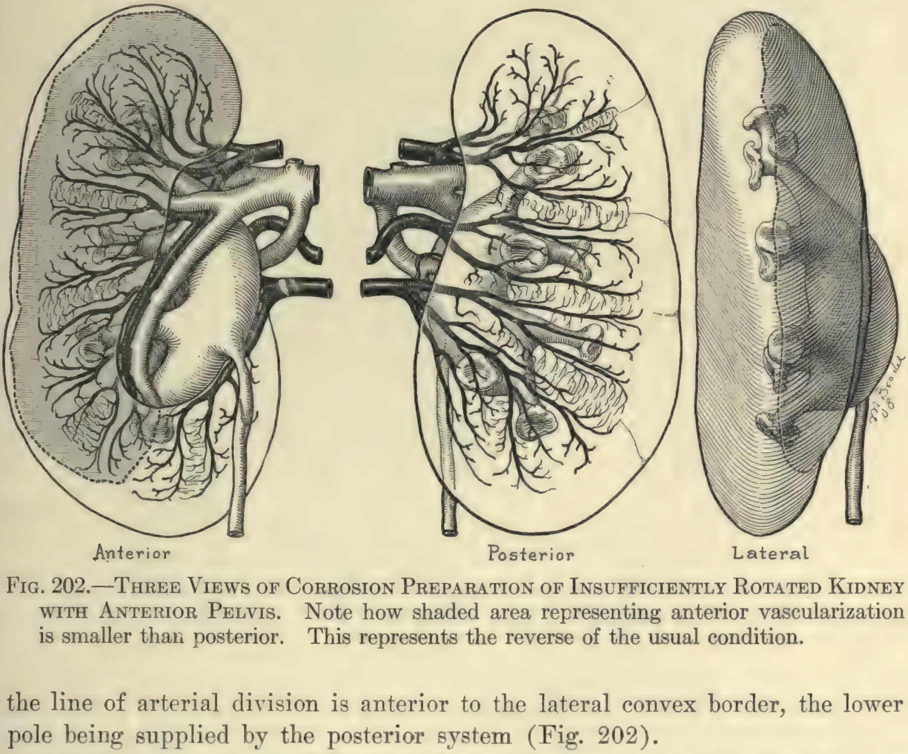


FIG. 202.—THREE VIEWS OF CORROSION PREPARATION OF INSUFFICIENTLY ROTATED KIDNEY WITH ANTERIOR PELVIS. Note how shaded area representing anterior vascularization is smaller than posterior. This represents the reverse of the usual condition.

the line of arterial division is anterior to the lateral convex border, the lower pole being supplied by the posterior system (Fig. 202).

(2) In cases of mesial pelvis the two systems are nearly equal, except that the lower pole is supplied by the anterior branch (Fig. 201).

(3) In cases of posterior pelvis the anterior arteries preponderate and the line of arterial division is posterior to the lateral convex border. The lower pole is always supplied by branches of the anterior system (Figures 198, 199 and 200).

The overwhelming majority of kidneys are of the third type, already described at length. There are, of course, many individual variations within this type, and so we find extreme cases where the posterior artery is very insignifi-

cant, and again others where it is nearly as large as the anterior. The best guide in the determination of the extent of the territory of the posterior artery is the posterior contour of the hilum. If the hilum forms a deep transverse notch (Fig. 198), the posterior artery is small and terminates early; if the posterior notch of the hilum is shallow, the artery is larger; and, if its curve is the same as that of the anterior notch, the two arterial systems are about equal

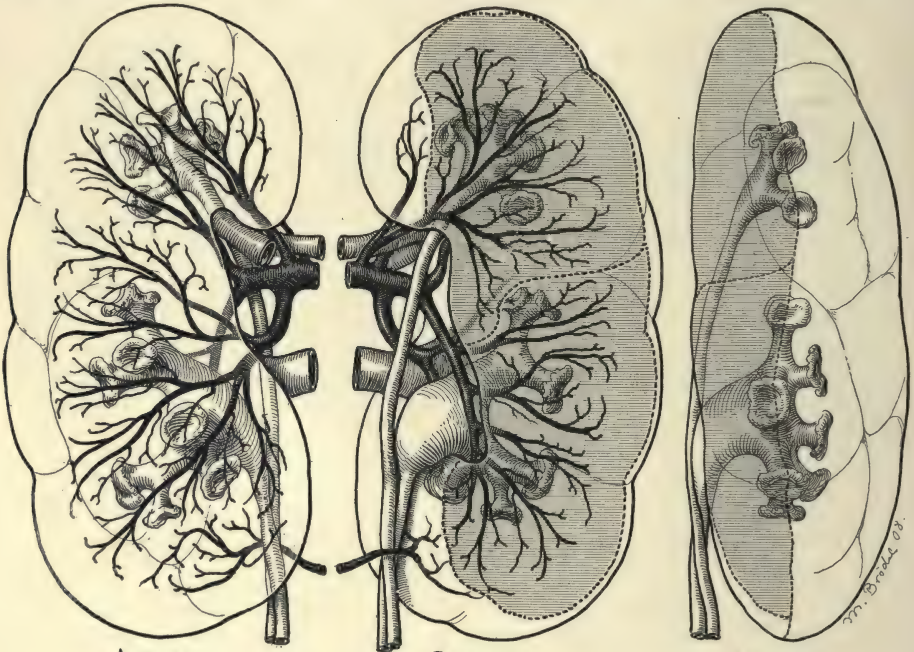


FIG. 203.—THREE VIEWS OF CORROSION PREPARATION OF KIDNEY WITH DOUBLE PELVIS. This represents, like the preceding figures, a type form. Note how complex the arterial circulation has become. There are now two posterior arteries, each skirting the renal pelvis as in a normal case. The lower posterior artery runs obliquely backward between the two renal pelves. The shaded areas represent the territory of the posterior vascularization.

(Fig. 201), and so forth. Rotation or torsion of the lower half frequently produces an oblique line of arterial division and an overlapping of the posterior system in its lower portion.

From a surgical standpoint the most unfavorable arrangement of the vessels is found in some kidneys with divided pelvis, in which a large arterial branch may curve from the anterior system between the two pelves over to the

posterior system. There are two oblique planes of arterial division in such kidneys, coinciding with the oblique axes of the two pelvic branches.

As a rule, however, the arterial circulation of kidneys with divided pelvis or double ureter conforms with the scheme laid down in Figure 203. There are two posterior arteries, the upper being derived in the usual manner, though quite short. The lower, being a branch of the anterior system, passes in front of the upper pelvic division, but curves soon toward the posterior region and skirts the posterior margin of the lower pelvic division just as in a normal kidney. The separate artery to the lower pole, however, is not characteristic of such cases. Its territory is usually supplied by the lowest branch of the anterior system.

According to various observers, irregularities of the renal arteries are said to occur in from 25 to 50 per cent. of cases, the instances of multiple arteries being the most frequent. It will be well to note briefly the different varieties and see how they affect distribution in the interior of the kidney.

(1) There may be two separate main arteries of equal or unequal caliber. Their distribution may be as follows:

(a) The upper artery supplies the upper pole and anterior surface; the lower artery supplies the lower pole and posterior surface.

(b) The upper artery supplies the upper portion of the kidney; the lower artery supplies its lower portion.

(c) The upper artery supplies the anterior surface; the lower artery supplies the posterior surface.

(d) The upper artery supplies the posterior surface; the lower artery supplies the anterior surface.

In each of the four types the plane of arterial division is in the usual place. In b there are two posterior arteries, which are of the same type as those found in kidneys with double pelvis (Fig. 203).

(2) In addition to the main artery or arteries there may be one or several smaller supernumerary arteries arising from the aorta and plunging into the cortex at various points between the two poles. The supernumerary twig may be so near as to twist around the main renal artery, and, again, it may be far away, running from the common iliac to the lower pole of a normally situated kidney. Figure 204 is a composite picture of the usual location of supernumerary arteries. The arteries may or may not have accompanying veins; as a rule they have not. As said before, the lobulated form of the kidney is very marked if these branches exist, and the entrance of the supernumerary artery is, as a rule, at the place of junction between two such lobes or pyramids. It plunges into a funnel-shaped depression of the capsule and makes its way through a

column of Bertin to the pelvis or major calyx, or else through the cortex directly to a point between two calices. Its further course is similar to that of the other arteries. It supplies only the near side of the two pyramids between which its course lies. If these vessels enter the kidney very high or very low, they may run directly to the base of the pyramid without touching a calyx, in which case they supply only the side of the pyramid which faces them. The supernumerary arteries are more frequent on the anterior surface and lower pole. The surgical significance of these separate arteries is evident. In extirpating a kidney the surgeon should always be on the lookout for supernumerary branches, which must be ligated separately. The distance between the arteries at their aortic origin varies between 1 and 10 cm., rarely more. In my series 40 per cent. of kidneys have either multiple or supernumerary arteries. The presence of these arteries does not affect the position of the plane of arterial division.

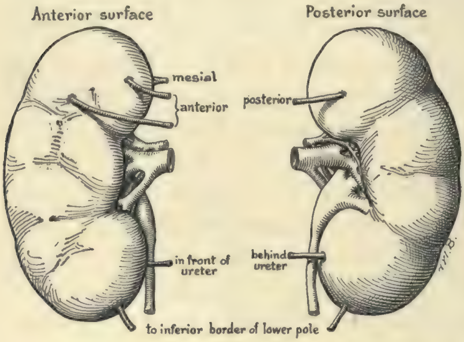


FIG. 204.—COMPOSITE PICTURE OF ANTERIOR AND POSTERIOR SURFACES OF THE KIDNEY, SHOWING THE FAVORITE POINTS OF ENTRANCE OF SUPERNUMERARY (ACCESSORY) ARTERIES. Those at upper pole may render a nephrectomy dangerous. Branches next to the ureter, either in front or behind, may be a factor in producing hydronephrosis.

(3) The renal artery may divide 4-5 cm. from the hilum into an unusually large number of branches, 4-7, or there may be from three to five separate arteries of nearly equal caliber, the lowermost of which may give rise to the spermatic artery. These anomalies have also no influence upon the plane of arterial division.

(4) The renal artery may arise at a lower point than usual, either from the aorta or its pelvic branches. Associated, as a rule, with the lower origin is multiplicity. This form is found in cases of ectopic kidney. If the various arteries enter the kidney from several sides, viz., right, left, above, or below, it is impossible to determine the plane or planes of arterial division with any degree of certainty.

(5) Both renal arteries may arise from one common trunk at the anterior surface of the aorta. In cases of ectopic kidneys and horseshoe kidneys this arrangement is frequently found. The plane of arterial division in the latter is usually in a more anterior position than is the case in normal kidneys.

(6) Instead of one, several capsular arteries may emerge from the surface of the kidney. Since it is of importance in renal surgery to know the usual position of these perforating branches, a diagram has been added, giving a com-

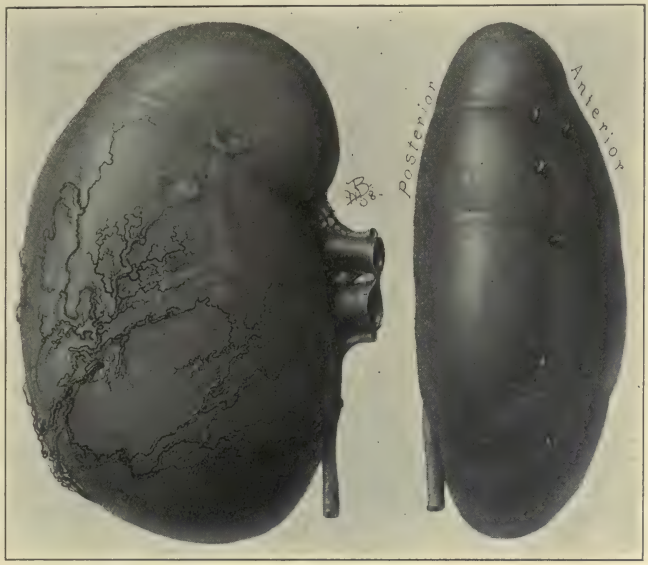


FIG. 205.—FIGURE TO RIGHT SHOWS FAVORITE POINTS OF EMERGENCE OF PERFORATING CAPSULAR ARTERY. Not every kidney has this perforating branch and it is rare to find more than one. Figure to the left shows distribution of perforating branch in fatty capsule, the fat being removed.

posite picture of all such vessels we have seen (Fig. 205). They emerge usually from the transverse or longitudinal columns of Bertin, and are, in my specimens, without exception, on the anterior surface.

Most capsular arteries, however, do not emerge through the parenchyma, but arise from a branch of the renal artery at the hilum (Fig. 206).

(7) The right artery may pass in front of the vena cava.

(8) The renal artery may be a branch of the following vessels:

(a) The inferior mesenteric artery (ectopic kidney).

(b) The middle sacral artery (ectopic kidney).

(9) On the other hand, the renal artery may give rise to the following branches:

(a) The inferior phrenic artery.

(b) An accessory hepatic artery.

(c) The middle adrenal artery.

(d) The spermatic or ovarian.

(e) An accessory pancreatic.

(f) An aberrant branch of the left renal artery may run in a furrow over the anterior surface of the kidney downward, passing in front of the M. psoas and emptying into the hypogastric artery.

FIG. 206.—CORROSION PREPARATION SHOWING ARTERIAL CIRCULATION OF THE PERIRENAL, FATTY CAPSULE DERIVED FROM BRANCH OF RENAL ARTERY AT THE HILUM. Each branch usually supplies only a part of the capsule, the one shown here being exceptionally large.

The Form of Infarcts (Fig. 207).—The radiating character of the larger blood vessels, each supplying a wedge-shaped piece of parenchyma, explains the varying forms of infarcts in the kidney. Infarcts may be caused: (1) by operative interference, viz., severing or ligating of a blood vessel; (2) by trauma, viz., tearing a blood vessel; or (3) by a pathological process, viz., thrombosis and embolus. The form of the infarct varies according to the seat of obstruction. If the latter is in one of the large vessels at the hilum, the infarct is wedge-shaped and of great extent, the base of the wedge being in the periphery, the apex toward the pelvis. The width is greater at the lateral border than at the hilum. A very short perpendicular incision at the hilum may suffice to produce this enormous destruction of kidney substance. If an incision of the same length and direction be placed further out toward the lateral border, the loss of substance becomes less, and so on, until the minimum destruction is experienced just inside the lateral border.

If the obstruction is in the cortical vessels or the arteries between cortex and medulla, the infarct is a parallelopipedon or a cube with margins only slightly diverging toward the surface. It may be merely a thin strip, if corresponding to only one or two interlobular arteries.

The separate polar circulation and the division into ventral and dorsal arterial circulation explain the so often observed isolation of blood-borne diseases, at least in the initial stages.

Resection of Portions of the Kidney.—A thorough knowledge of the arterial circulation, especially of the larger vessels, is very important in resections of

the kidney. Portions of the anterior and posterior half are best resected by incisions radiating from the hilum, the resected portion being narrower toward the interior. The resection of the poles requires similar radiating incisions, not merely transverse. Resection of a diseased area in the lateral region is best done through longitudinal incisions similar to the nephrotomy incision. As Zondek [1] points out, the blood-borne disease often appears as a circumscribed

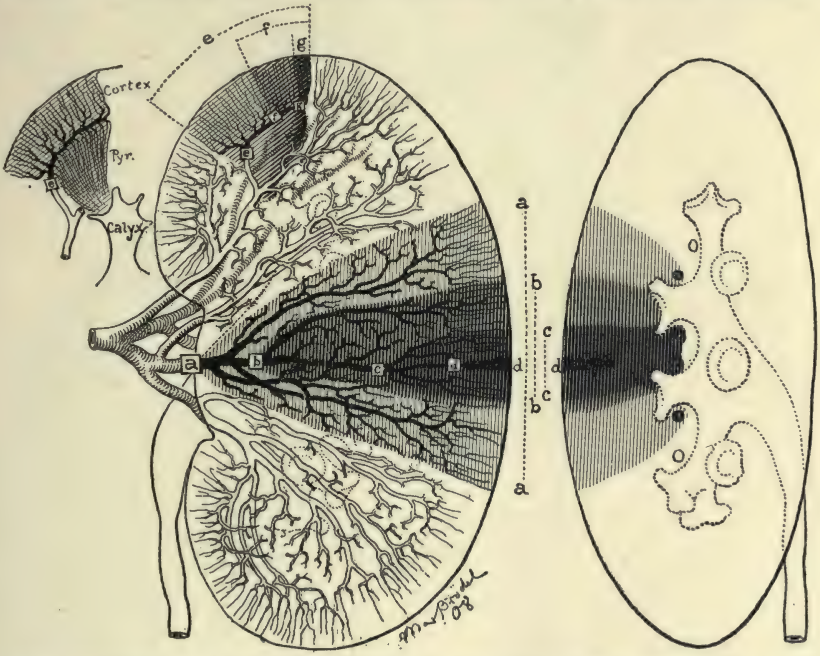


FIG. 207.—DIAGRAM OF CORROSION PREPARATION SHOWING EXTENT AND FORM OF ARTERIAL INFARCTS. The extent of the infarcts of the complete obstruction at a, b, c, and d is shown by variously shaded corresponding areas. The figure to the right shows the lateral projection of the same areas. Infarcts caused by obstructions at e, f, and g show type of polar infarcts. Note how infarcts assume the shape of a cone, with the apex at the point of obstruction, the base at the renal surface.

area on the surface, corresponding to the territory of the blood vessels. This is a safe guide in the removal of the diseased area. He likewise suggests temporary clamping of the corresponding artery in cases where any doubt as to the margins exists. The region of the clamped artery becomes pale within a few seconds, and, if the branch is found to be the one desired, it is ligated and

[1] M. Zondek, "Die Topographie der Niere und ihre Bedeutung für die Nierenchirurgie," Berlin, 1903.

resected with its territory. It is advisable to begin resection at the main branch and extend it toward the periphery. Semiblunt resection is preferable to sharp.

The subcutaneous tears of the kidney following violent trauma occur, as a rule, in the interspaces between the large arteries. Such tears radiate from the hilum toward the lateral border, or else one pole (the lower more frequently) may be torn from the rest of the organ. The depth of the tear is variable and may reach the calices and even the pelvis.

THE VEINS.

The interlobular veins in the cortical substance are divisible into superficial and deep veins. The superficial veins drain toward the surface into

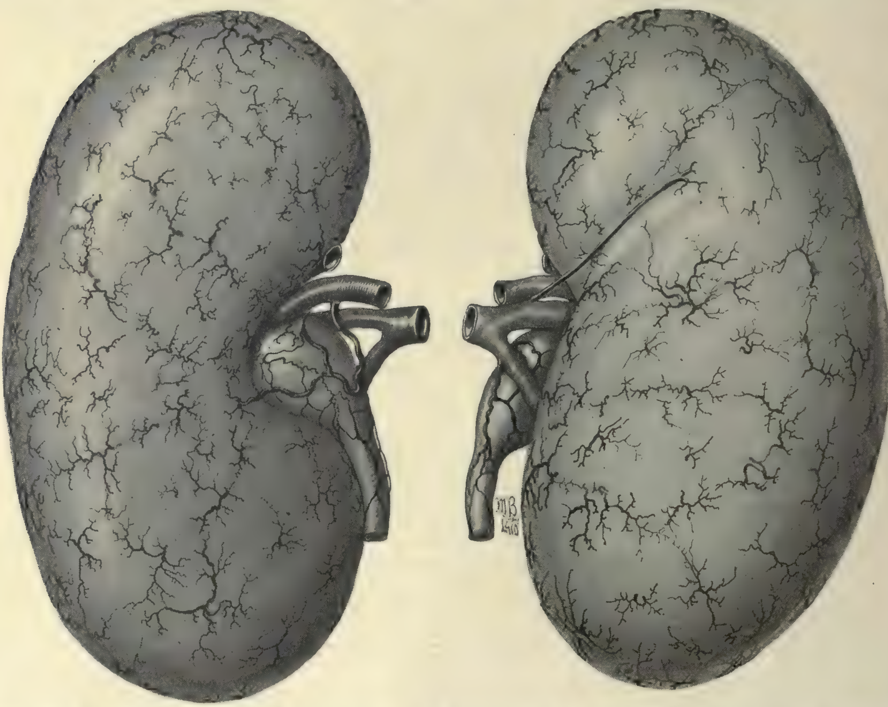


Fig. 208.—Stellate Veins of Capsule. Posterior view to the left; anterior, to the right. The arrangement of these veins is very important since they represent topographical landmarks. Hold the picture at a distance and note how the large veins form continuous lines corresponding to the location of the columns of Bertin, which carry the large blood-vessels in the depth. We have thus a means of determining the boundaries of lobes even when the surface of the kidney is perfectly smooth.

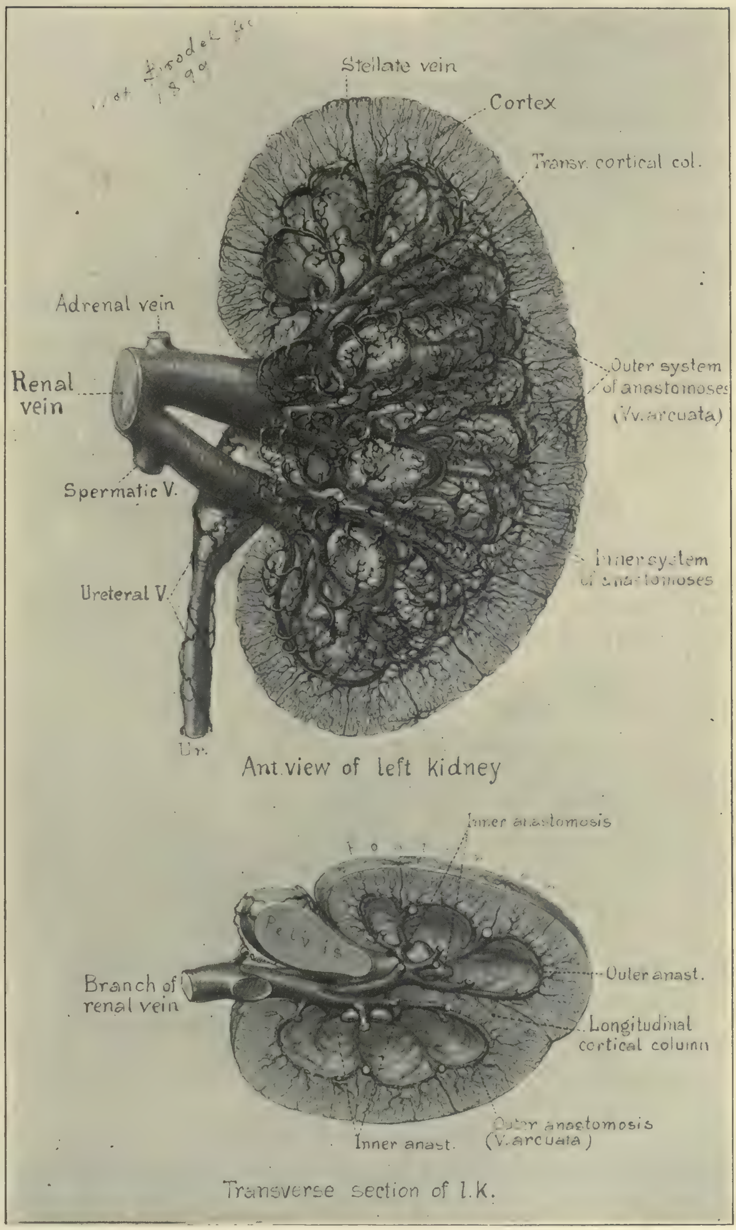


FIG. 209.—CORROSION PREPARATION OF VENOUS SYSTEM OF NORMAL KIDNEY.

subcapsular channels. From 3-7 of these channels converge to one point, forming the characteristic stellate veins of the capsule, which may reach considerable size (0.2 to 0.8 mm. in diameter), and spread out on the surface over an area varying from 0.5 to almost 2 cm. square. Although they are seen in fairly regular intervals of 1 to 1½ cm. plunging into the cortex, they are larger and more numerous at the line of division between the pyramids, and in kidneys having lost their fetal lobulation the position of the pyramids can still be recognized by means of the stellate veins of the capsule (Fig. 208). The large stellate veins run into the large trunks at the margin between the pyramids and the columns of Bertin. The smaller ones run into the venous arches and the veins at the base of the pyramid. A corrosion preparation of these stellate veins resembles a forest of minute palm trees planted on the vascular roots of the base of the pyramids. Save for a few small anastomoses, there is no communication between the stellate veins of the capsule on the surface (Fig. 209).

The deep cortical branches collect the blood from the capillaries of the deeper portions of the cortical substance and empty into the convex side of the arches. The greater number of the cortical veins are of this variety. The capillaries of the medullary substance collect in veins (venulæ rectæ), which run likewise into the arches, but at their concave border. These arches may be situated at varying distances from the papilla, being nearest in the case of a divided pyramid and farthest in the case of a single large pyramid (Fig. 209).

The collecting veins around the sides of the pyramids are twice to three times the thickness of the corresponding interlobar arteries, and are, as is the case throughout their course, situated nearer to the pyramid than the artery. Their curved course and thickness are the cause of the peculiar lobulated form of the pyramids, each groove in the pyramid being filled by one or more of these veins. The entire pyramid is thus surrounded by a large number of venous arches, running in various directions, and draining into the veins surrounding the calices. Around the calices near the fornices, preferably the anterior group, these veins often form thick rings or loops (Fig. 209), upon which the above-described system of arches is situated. There are, therefore, two systems of anastomosing veins in the kidney: one at the apex and another at the base of the pyramids.

In a large number of injections there is no large collecting vein posterior to the pelvis, the veins of the posterior row of pyramids collecting in little short stems which run between the posterior major calices to the veins hugging the anterior calices. Between the anterior and posterior rows of calices they form an irregular chain of anastomosing vessels, which Hauch has called "median

vein." Sometimes the posterior vein does not drain into the anterior system, but runs independently toward the hilum. Similar to the anterior veins, the posterior veins form anastomoses with their neighboring fellows. Veins may pass posterior to the pelvis, but if they do, they are found around either the upper or lower polar calyx, in which case they drain obliquely forward, or one small vein may accompany the posterior branch of the renal artery. This branch anastomoses within the ureteral veins. In cases of divided pelvis one or two large veins may lodge in the interval between the pelvic divisions. The course of these veins is generally obliquely forward and the above-mentioned longitudinal median vein is lacking. If a solitary median major calyx is in its way, the vein splits and forms a thick venous ring around the neck of that calyx.

In comparing the arrangement of the arteries with that of the veins we find that the non-vascular plane exists only as far as the arterial circulation is concerned, since the veins cross from the dorsal to the ventral half of the kidney, and that an incision through the posterior row of calices would strike a varying number of venous arches between cortex and medulla and about six of the intercalical veins, as shown in Figure 210. The polar veins and small posterior vein, however, are of sufficient caliber to carry the blood of the posterior portion of the kidney, even if the central anastomoses are cut.

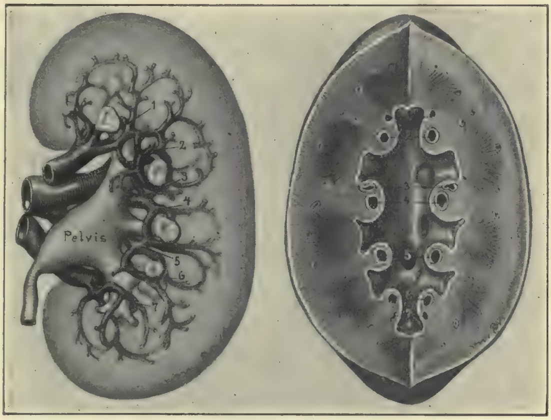


Fig. 210.—Corrosion Preparation of Large Venous Trunks. Figure to the left shows view from behind. Figure to right shows similar kidney laid open as in nephrotomy. Note how large veins have been severed between the calices. This does not interfere with the venous outflow from posterior half of kidney, as venous arches and ample polar anastomoses take care of it.

The veins collect on the ventral wall of the pelvis in three large trunks of 6-7 mm. in diameter, the upper two of which, as a rule, unite into one large branch 8-9 mm. in diameter. The lower vein is somewhat smaller, measuring only 6-7 mm. These two large veins are seen emerging at the hilum in front of the ureter, where they pass anterior to the artery. They may unite to

form one single vein, 12-16 mm. in diameter, anywhere between hilum and vena cava, or they may empty separately into the latter. Occasionally there are three veins emptying separately into the vena cava. Some of the smaller veins, however, do not always join the main trunk inside the hilum, but pursue an independent course toward the vena cava or to the renal vein near its terminus. Not infrequently there are supernumerary veins coming from the parenchyma on the lateral, anterior, posterior, but preferably the median surface. They may unite with the renal or spermatic veins or drain directly into the vena cava. The plane of the arteries crosses the plane of the veins just at the hilum.

The veins surrounding the kidney come from the fatty capsule. They are more numerous on the dorsum of the kidney, where the fat is of greater thickness. While some drain into the veins of the posterior abdominal wall, others empty into the spermatic, ureteral, and adrenal veins. Most of them accompany the renal artery at the hilum, together with the veins of the renal pelvis. Sometimes, however, they perforate the fibrous capsule and join the venous arches of the kidney. Hence the two forms of capsular hemorrhage, due to an injury to these veins: (1) hemorrhage spreading from the hilum in an outward direction; or (2) a circumscribed hemorrhagic area on the lateral, anterior, or posterior surface.

Both renal veins run into the vena cava at a level somewhat lower than the level of the renal arteries. The right vein stands slightly lower and is much shorter than the left, which receives as tributaries, from above the adrenal, from below the spermatic, vein. Supernumerary veins are not as frequent as supernumerary arteries, and if the artery is seen dividing into four or five branches near its aortic origin the veins gather usually near the hilum into one thick vessel, which then runs somewhat obliquely up toward the vena cava.

While the renal vein and its branches have no valves, there is often noticeable a narrowing of the lumen at the junction of two vessels, i. e., the peripheral portion is thicker than the central portion. This is true especially in the case of the larger vessels, viz., the narrowing of the renal vein at its point of junction with the aorta being quite marked. Zondek points out that this mechanism might be considered as a means of reducing the velocity of the blood current in the kidney.

Anomalies of Renal Veins.—The following are the anomalies of the renal veins:

(1) The left vein may pass behind the aorta.

(2) Both renal veins may run obliquely upward at an angle of 45 degrees by low position of the kidney.

(3) They may run obliquely downward at an angle of 45 degrees with the median line and join the vena cava near the promontory.

(4) The left vein may receive a lumbar vein.

(5) The right vein may receive the adrenal vein or an accessory adrenal vein, or in addition a spermatic or ovarian vein.

(6) There may be accessory renal veins, usually at the upper pole. They may join veins from the liver and run as a separate trunk to the vena cava.

(7) In congenital displacements of the kidney the renal veins may drain into any of the neighboring tributaries of the vena cava, such as the common or internal iliac or into the middle sacral veins; or, as in horseshoe kidneys, the veins may unite in one vessel which empties into the anterior wall of the vena cava.

SURFACE OF THE KIDNEY AND ITS LANDMARKS IN NEPHROTOMY.

Let us now examine the surface of the kidney and see in which way its form and vascular elements indicate the underlying structures. A thorough knowledge of the surface of the kidney is required if a surgeon wishes to place his incision so that he cuts down into the least vascular area.

The form of the kidney depends largely upon the number and position of the pyramids (Fig. 100). The upper and lower pole each have one, which may be subdivided into two or three apparently individual pyramids. The bases of these pyramids face the median surface of the kidney and may extend more or less to the anterior, posterior, or lateral surface. The upper and lower pyramids are by far the largest. The rest of the kidney has, as a rule, three anterior and as many posterior pyramids. The long diameter of the base of the pyramids lies in an approximately horizontal direction and measures 4-6 cm. in the posterior pyramids and 3-4 cm. in the anterior pyramids. The anterior pyramids are, therefore, generally shorter and thicker, while the posterior ones are longer and more slender. The apex is about 1.5 cm. away from the nearest point of the base. Between these eight pyramids are the columns of Bertin or cortical substance, dipping down into the sinus. There are generally four on each side. They have a width of from 5-7 mm. and run from the hilum, diverging to the lateral border, where they join a long column running between the anterior and posterior rows of pyramids.

As the posterior row has longer pyramids, as a rule, it somewhat overlaps the middle line, and the lateral longitudinal column referred to above is consequently found somewhat anterior to the lateral convex border of the kidney.

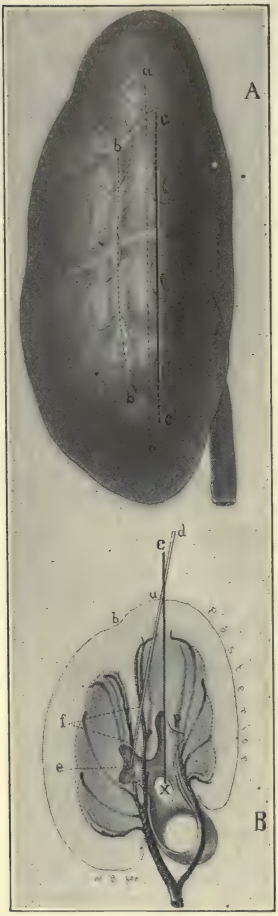


Fig. 211.—Position of Nephrotomy Incision in Most Frequent Type of Kidney. (Upper figure.) This is indicated by the line c–c′ which is just posterior to the convex border of the kidney, indicated by dotted line a–a′. Anterior to the convex border is line made by longitudinal column of Bertin, containing vascular trunks b–b′. This is so-called *white line* and should be avoided. The line c–c′ indicates plane of vascular cleavage. The lower picture shows in cross section the anatomical relations. Note difference between safe incision c–x and unsafe incision d–e. Both start correctly, but the latter cuts through large arteries in depth at f.

Figure 211 shows the lateral view of a kidney with its pyramids, their calices, and the lateral longitudinal columns, marked on the surface by a white line dividing the two rows of pyramids. The lower figure shows that this column carries the greatest number of arteries, while a short distance posterior to this region there is the arterial division, through which an incision should be directed.

As was shown on page 425 this column may be at the lateral border or even somewhat leaning toward the posterior surface. This would demand a still more posterior incision. This lateral column is a most important landmark and should in every nephrotomy be carefully mapped out. In lobulated kidneys it is indicated by a distinct depression on the surface. The capsule is thickened along this line and forms frequently a whitish band to which the perirenal fat appears more intimately attached than elsewhere. This closer attachment is due to perforating capsular vessels.

Lobulation in different degrees of distinctness is found in the great majority of cases. A trained eye can detect a lobulation in kidneys which to an untrained one would appear per-

fectly smooth. Figure 211 shows the characteristic appearance of the lateral surface of the kidney; b-b′ is the depression indicating the lateral longitudinal column; a-a′ is the lateral convex border; and c-c′ would indicate the line of incision through the non-vascular plane.

Should the kidney show not the slightest depression or lobulation the arrangement of the stellate veins of the capsule suffices to map out the number and limits of the pyramids, and thus enables the surgeon to place his incision in a proper direction (Fig. 208). On page 434 attention was called to the fact that the largest and most conspicuous veins are seen at the junction between the base of the pyramids and the columns of Bertin. They are situated in rows, dividing the surface into sections, which, on careful examination, are found to be geometrical projections of the pyramids or subdivisions of such on the surface.

In order to render this description of the surface as complete as possible we add data touching upon the various more or less abnormal forms, and indicate the most probable corresponding type of the structure in the interior:

(1) A thick round kidney usually signifies	1. Normal arteries 2. Simple pelvis 3. Smooth surface
(2) A long and slender kidney usually signifies	1. Abnormal arteries 2. Divided pelvis or double ureter 3. Lobulated surface
(3) The furrows and depressions on the surface correspond to	The cortical columns, and in the depth the large blood vessels
(4) The elevations on the surface correspond to	1. The pyramids, and in the depth the calices 2. The least vascular areas
(5) The two notches of the hilum on the anterior side correspond to	1. The major calices or divided pelvis 2. The main branches of the artery
(6) A single anterior notch at upper end of hilum, caused by torsion of lower half of kidney in the posterior direction signifies	1. The lower anterior calices are found very near the median border of the kidney 2. The lower posterior calices are directed laterally
(7) A shallow posterior notch at the hilum signifies	1. A long and large posterior artery 2. The plane of arterial division near convex border
(8) A deep transverse posterior notch at the hilum signifies	1. A short posterior artery 2. The plane of arterial division far posterior 3. Absence of middle posterior calyx

(9) Transverse groove on lateral convex border signifies	1. Divided pelvis 2. Deep transverse cortical column 3. Abnormal vascularization
(10) A narrow slit-like hilum signifies	1. Normal arteries 2. Smooth surface 3. Simple pelvis, usually intrarenal 4. Short incision required to open pelvis (4–5 cm.)
(11) A wide, long-drawn-out hilum signifies	1. Abnormal arteries 2. Lobulated surface 3. Divided pelvis, usually extrarenal, or double ureter 4. Long incision required to open pelvis (6–7 cm.)
(12) Intrarenal pelvis signifies	1. Short hilum 2. Short calices 3. Moderately thick parenchyma 4. Shallow cortical columns 5. Depth of incision 2–3 cm.
(13) Extrarenal pelvis signifies	1. Long hilum 2. Long calices 3. Thick parenchyma 4. Deep cortical columns 5. Depth of incision 3–4 cm., or several incisions.
(14) Mesio-anterior pelvis, anterior line of hilum receding signifies	1. Anterior arterial system small, posterior large 2. Anterior pyramids overlapping into posterior territory 3. Plane of arterial division anterior to lateral convex border
(15) Mesial pelvis, anterior contour of hilum similar to posterior signifies	1. Anterior arterial system equal to posterior 2. Symmetrical arrangement of anterior and posterior pyramids 3. Plane of arterial division at lateral convex border
(16) Mesio-posterior pelvis, posterior contour of hilum receding signifies	1. Anterior arterial system, large, posterior, small 2. Posterior pyramids overlapping into anterior territory 3. Plane of arterial division posterior to lateral convex border
(17) Supernumerary arteries signifies	1. Probably abnormal pelvis, or double ureter 2. Probably lobulated surface
(18) Marked lobulation signifies	1. Abnormal pelvis or double ureter 2. Multiple or supernumerary arteries

(19) Kidney in a low position (congenital) signifies	1. Anterior pelvis, anterior hilum 2. All calices post. or lateral 3. Abnormal vessels
(20) S-shaped curve of kidney, upper pole forward, lower pole backward signifies	An oblique line of arterial division, from ventro-lateral (upper pole) to dorso-lateral (lower pole)

PYELOTOMY.

The principal field for pyelotomy is in connection with the removal of stones from the kidney. The indications and contra-indications are discussed fully in Chapter XX.

The procedure is of little value in exploring the pelvis for new growths or the origin of hemorrhage. It has been employed as a substitute for nephrotomy in certain infections of the kidney. The considerations here appended are principally in connection with kidneys which are but little altered in gross appearance and in which the pelvis is not greatly distended. The opening of a greatly distended pelvis is a very simple matter, is entirely bloodless, and is a preliminary procedure in many operations for hydronephrosis, as well as stone. In some cases, as pointed out in Chapter XX, page 139, it is an extremely simple procedure to open the pelvis to remove a stone and to close the incision without hemorrhage and without any injury to the kidney. For the successful carrying out of this procedure a perfect exposure must be obtained. It is of advantage to deliver the kidney into the incision when this is possible. We have frequently, however, removed stones with the kidney in the depth of the wound. The method is not applicable where there are numerous or very large stones, or where the stones are high up in the kidney parenchyma. Many kidneys have two, three, or even four major calices which may be so narrow that it is impossible to extract even a small stone through them (Fig. 212). The same difficulty is met where the pelvis divides outside of the kidney and the major calices at their entrance to the hilum are not larger than the average-sized ureter. Furthermore, the minor calices may form such a complex cavity in the interior of the kidney that an attempt to locate a small stone through the hilum incision will fail.

When dealing with kidneys having a roomy, well-defined, extrarenal pelvis it is well to begin all explorations for moderately sized calculi with the pelvic incision and extend it obliquely through the posterior parenchyma in a caudal direction, as shown in Figure 213. This opens the greater part of the pelvis and is almost bloodless. The extension can also be made without cutting any parenchyma at all. Scissors are inserted, one blade into the

calyx, the other into the renal sinus, and the calyx split as far as the papilla. Exploration of the pelvis through the small opening, however, is not quite satisfactory, and the parenchymal cut appears preferable. The renal end of this L-shaped incision is the key for a safe longitudinal incision through the lateral convex border, should the nature of the case demand a further exten-

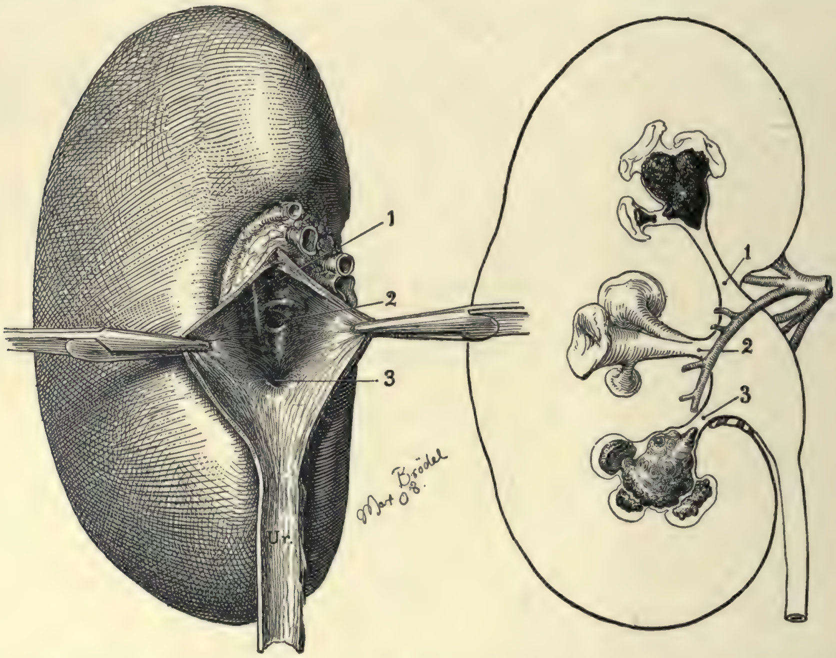


FIG. 212.—KIDNEY WITH STONES IN UPPER AND LOWER CALICES, WITH NARROW NECKS 1, 2 AND 3. Note impossibility of removing such stones through pyelotomy incision.

sion of the incision (see page 444). This leads us to the consideration of the classic parenchymal incision and its dangers.

If, when tried, the pelvic incision is too small for the removal of the calculus, it must be borne in mind that it cannot be enlarged in an upward direction, owing to the posterior branch of the renal artery, which is a constant large vessel skirting the pelvis, as shown in Figure 199. The incision may be enlarged safely in an oblique direction, downward and outward, over the posterior surface of the kidney, as shown in Figure 213. By this procedure it is possible to combine pyelotomy with nephrotomy. It is sometimes convenient to remove a part of the stone through the pelvic incision and the other part or

parts through the nephrotomy opening. These incisions in the pelvis heal well in cases where there is not much or no infection of the kidney, and where there is free drainage through the ureter. They should be closed by suture in layers where possible (see Fig. 349). Attempts to systematize the procedures are difficult, but we believe that the plan submitted below will prove of help in most cases.

NEPHROLITHOTOMY.

As the operations on the kidney are generally of an extra-peritoneal character, the kidney is almost invariably exposed at its lower pole or convex border. A longitudinal incision made through this region of the kidney down into its pelvis may be, as has been noted, almost bloodless, but in a number of cases distressing hemorrhage has been experienced, which could not be controlled by packing and which was so severe as to render the subsequent removal of the kidney imperative. The reason that some incisions are accompanied by so little and others by so much hemorrhage lies in the fact that in every kidney there exists a plane of arterial division, and that a very short distance, i. e., about 5 mm., ventral and dorsal of this plane there is a vast number of arteries and veins stretching from one pole of the kidney to the other, the arteries being as large as 2 mm. in diameter, the veins up to 4 mm. and even more. They run parallel to the relatively non-vascular plane to the region of the arches at the base of the pyramids, where the cortical zone begins with its delicate and evenly distributed glomeruli-bearing arteries. The arterial division is caused by the pelvis and its branches, which obstruct the path of the arteries and cause them to part in two systems of unequal size (see Development). If the pelvis is capacious the arterial systems are far apart; if the pelvis is small and collapsed the arteries are close together. It is, therefore, evident that an incision from the surface down into the pelvis, even if the operator has started with the correct line on the surface, may very often fail to remain between the two vascular sheets. If, however, the operator is familiar with the form of the kidney, its underlying structures, and the variations of its blood supply, and if the following directions are adopted, the longitudinal incision just posterior to the convex border is the safest and most satisfactory in the majority of cases. It must be said, however, that the calices, in a few instances, form very complex cavities, minor calices giving rise again to secondary minor calices, so that even if the kidney be opened from pole to pole, an operator cannot always guarantee that all the pockets have been explored, and palpation of the two halves is by no means a satisfactory method of detecting a small-sized stone.

In case of stone kidney, if the calculus can be felt through the kidney substance, it has generally attained considerable size, and, as a consequence, much of the surrounding renal parenchyma has ceased to functionate. In such kidneys there will be little hemorrhage following the lateral incision, no matter how directed, the only bleeding of any extent coming from the vessels of the capsule and perirenal fat or from the surrounding adherent viscera. Such cases, however, are of less interest, since it is the kidneys in the early stages of the disease, with little or no parenchymal destruction and unimpaired circulation, the surgeon wishes to save, and in these the danger of hemorrhage is greatest. Fortunately such kidneys are also the least adherent, a great advantage for the necessary inspection prior to the selection of the best incision.

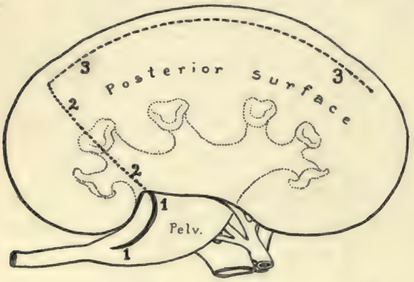


FIG. 213.—THE MOST BLOODLESS INCISION POSSIBLE FOR OPENING PELVIS AND KIDNEY. 1 indicates pyelotomy incision; this can be carried obliquely upward through renal parenchyma, as shown in 2, thus opening lower calices. Continued around parallel to transverse border, as shown in 3, the entire pelvis is laid open.

Possible variations of the renal vascularization are discovered by employing the following procedure (see also Rotation of the Kidney and Its Influence upon the Renal Vascularization, p. 133). The operator can readily determine by visual examination, or, better still, by palpation, what type of kidney he has to deal with. The tactile sense is more acute, especially in the depth of the wound. The palpating hand is more apt to recognize a pulsating artery than the eye. Both hands are inserted, one along the anterior, the other along the posterior renal surface. The hands should slowly advance *parallel* to one another and in the direction of the aorta. In doing so the surface characteristics of the kidney are carefully noted, especially the notches at the hilum.

(1) If the anterior hand encounters pulsating vessels under the protruding renal parenchyma, while the posterior hand feels the hilum containing the pelvis at the same level or a higher, it is certain that the plane of arterial division is *just posterior to the lateral convex border.*

(2) If both hands simultaneously encounter pulsating arteries under the parenchymal lips at the hilum, neither being able to detect a deep notch at the hilum, the plane of arterial division is *at the lateral convex border.*

(3) If the anterior hand encounters a deep anterior notch while the posterior hand at the same level still feels the bulging parenchyma with pulsating

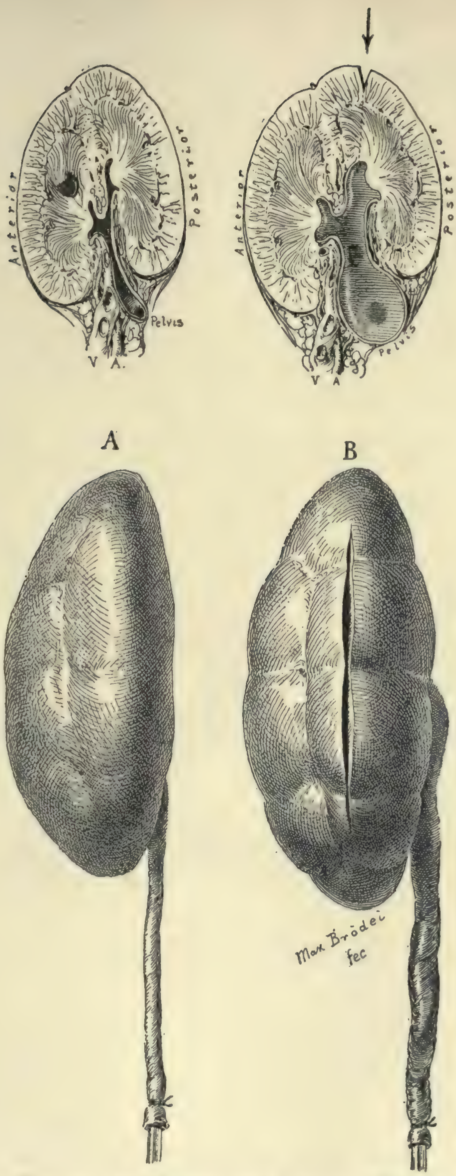


Fig. 214.—Collapsed Pelvis and Distended Pelvis. Figures to the left-hand side show kidney in transverse section and from the lateral view, in state of collapsed pelvis. Figures to the right show same kidney with distended pelvis. With pelvis distended, it is easier to strike calyx in preparatory pushing in of knife or needle to open kidney from within outward. The distention is produced, after exposing kidney, by injecting sterile fluid through renal catheters put in place before operation.

arteries beneath, it is certain that the plane of arterial division is just anterior to the lateral convex border.

TECHNIQUE OF INCISION.

The location, length, and direction of the incision must of necessity vary with the purpose for which it is made. A small stone in the pelvis or one easily accessible from the hilum is extracted by pyelotomy (Fig. 348). A larger stone in the lower half of the pelvis requires a parenchymal extension of the incision, while larger stones or calcareous fragments scattered throughout the pockets of a pelvis necessitate a longitudinal extension, laying the whole kidney open. This same extensive incision is required for explorations of the kidney in cases of suspected calculi, obscure diseases, or diffuse pathological conditions.

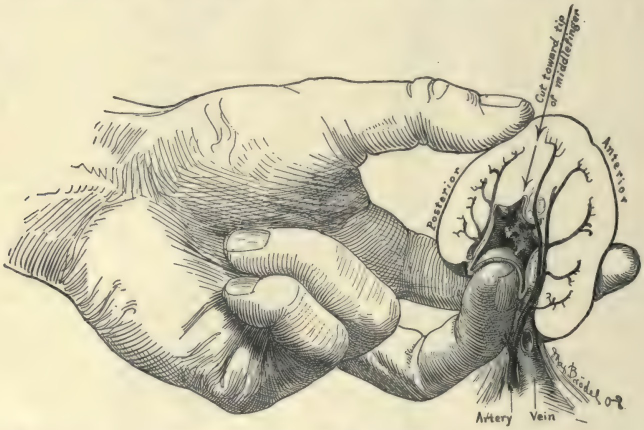


FIG. 215.—ANOTHER METHOD OF RENDERING ACCESS TO PELVIS SIMPLER. Suggested by Zondek.

All incisions into the kidney must have one principle in common, a principle which is based on the fact that the branches of a bush are much more readily separated if divided from within out than the reverse.

The incision may be made with a curved knife, or, better still, with a wire or strong thread, as described later. The renal arterial trees resemble the stems and branches of a bush, and with a walking cane two very convincing experiments can be made. It will be found next to impossible to introduce the cane into the center of the bush by pushing from the top down. On the other hand, by thrusting the cane into the center of the bush it can be readily lifted

up to the top; the branches simply bend to the right and left without being injured in the least. The same is true with a delicate celloidin corrosion of the renal arteries and a small glass rod for a cane. It appears, therefore, rational to begin the incision at the pelvis and cut from it upward to the surface.

The collapsed pelvis represents a narrow strip of tissue in the center of the kidney, and, in order to make it easier to locate, it is distended from below by injecting a suitable solution into it through a renal catheter (Fig. 214). Zondek recommends the inversion of the pelvis at the hilum with the finger as a means of separating the two arterial systems preparatory to the splitting of the kidney (Fig. 215). The best way, however, and the surest, is a small incision into the posterior surface of the pelvis with subsequent extension obliquely across the posterior parenchyma to the lateral border, until the entire lower posterior calyx is opened. No arteries are cut, for this is the posterior line of arterial division. The pelvic incision may be dispensed with, as shown in Figure 211. This is the key to the situation, for it permits the reintroduction of the cutting instrument into the pelvis preparatory to the longitudinal incision which opens the entire kidney (Fig. 216).

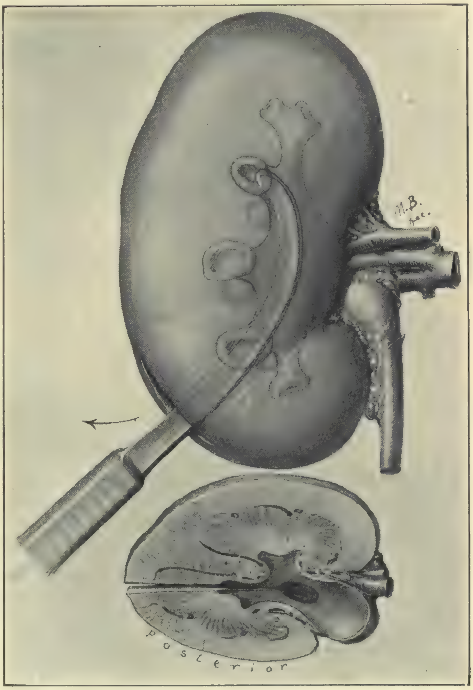


Fig. 216.—Opening Kidney from Within Outward by Means of Curved Knife to Avoid Injury of Vascular Trunks.

In cases of anterior renal pelvis this oblique incision is made across the lower anterior surface. If the calculus is in the upper portion of the pelvis and cannot be reached through the lower opening, it is well to determine first whether the pelvis is of the divided type, in which case a second, separate opening would be preferable. This is done to avoid cutting through the very vascular, deep, transverse cortical column found in kidneys with divided pelves. Through the lower pelvic incision a curved probe is inserted into the upper pelvis in order to determine the length and direction of the second incision. As will be shown, however, the wire

method is also preferable in such cases. Should the probing determine that the kidney substance between the upper and lower pelvis exceeds 3 cm. in thickness, it is advisable to look for a central pelvic branch, which may contain a calculus.

THE SILVER WIRE METHOD OF NEPHROTOMY.

As the experiments of E. K. Cullen and H. F. Derge (*Johns Hopkins Hosp. Bull.,* 1909, xx, 350) have shown, splendid results are obtained by

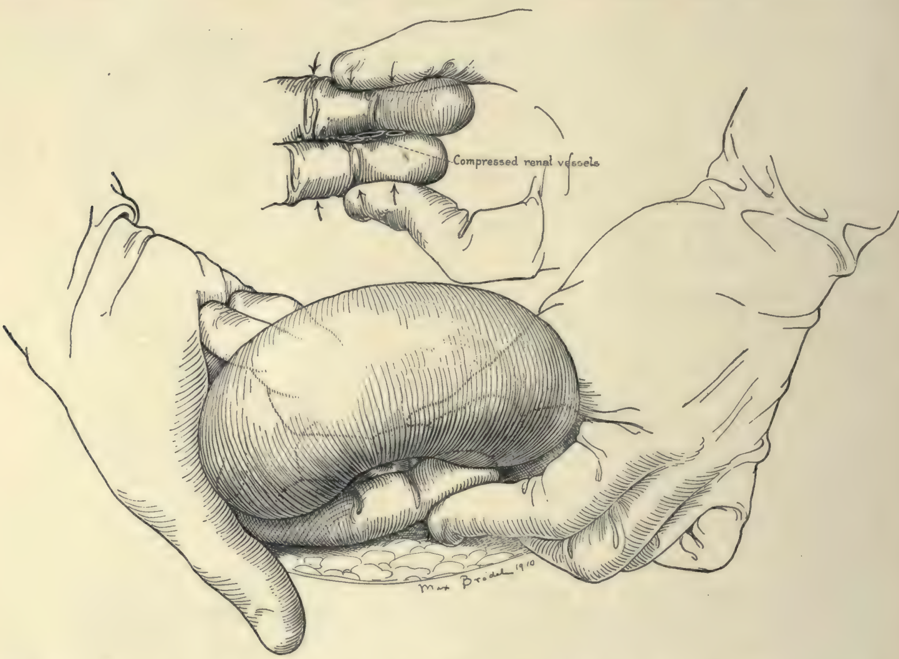


FIG. 217.—METHOD OF COMPRESSING RENAL VESSELS WHEN KIDNEY IS DELIVERED THROUGH INCISION. This minimizes hemorrhage occasioned by nephrotomy incision.

using silver wire as the cutting instrument. "A No. III silver wire was used, its pliability and low tensile strength making it almost impossible to tear any of the larger renal vessels, providing ordinary care is exercised in pulling the wire outward." This method has now been employed in a number of cases with very satisfactory results; in no instance has there been any severe

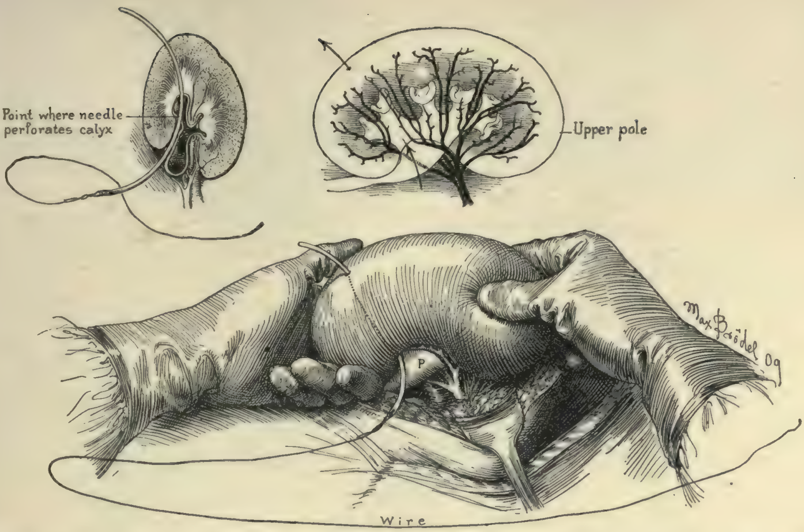


FIG. 218.—FIRST STEP IN SILVER WIRE METHOD OF OPENING KIDNEY. Point of perforation of posterior calyx shown by upper picture to left (kidney shown in cross-section). Upper picture to the right shows how incision avoids crossing arterial trunks. Note dotted line on surface of kidney (lower picture). This represents incision through fibrous capsule. After E. K. Cullen and Derge.

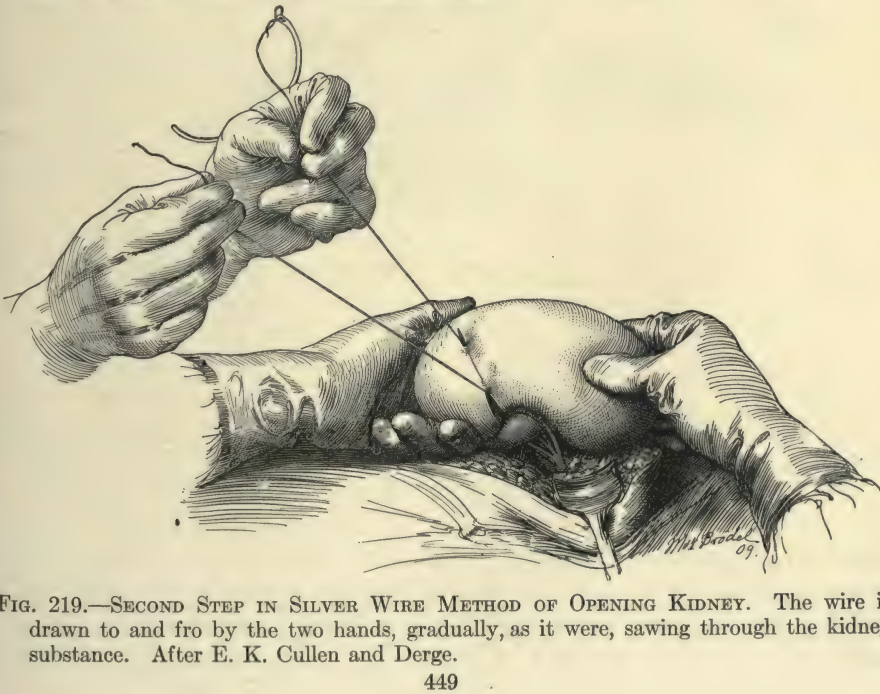


FIG. 219.—SECOND STEP IN SILVER WIRE METHOD OF OPENING KIDNEY. The wire is drawn to and fro by the two hands, gradually, as it were, sawing through the kidney substance. After E. K. Cullen and Derge.

post-operative hemorrhage, and the hemorrhage at the time of operation has been small.

The kidney is held between thumb and finger of the assistant, as shown in Figure 217. A short incision is made in the pelvis through which a No. III

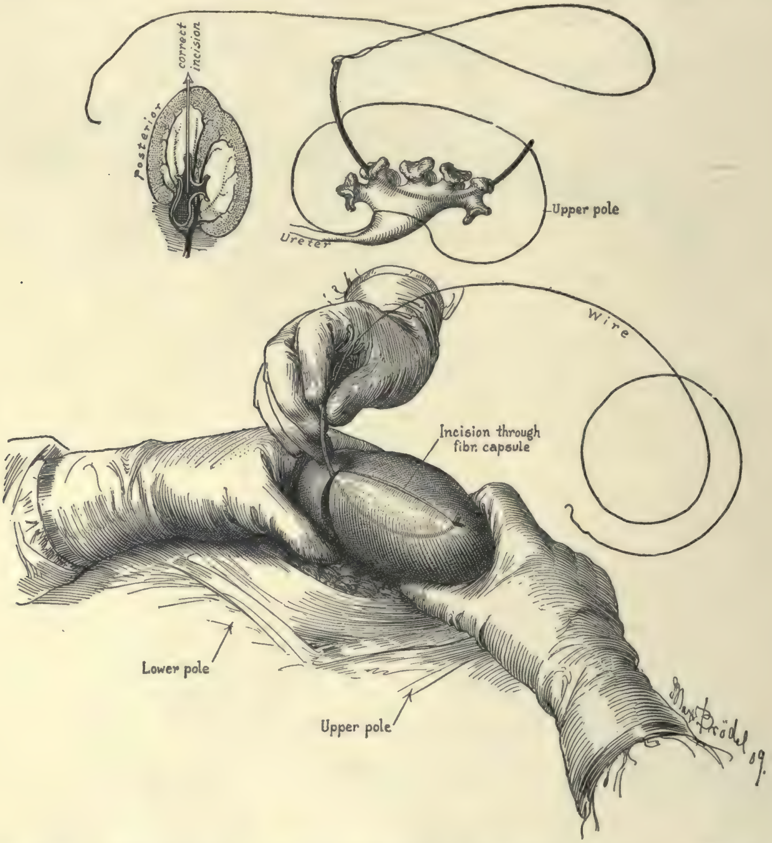


FIG. 220.—THIRD STEP IN SILVER WIRE METHOD OF OPENING KIDNEY. This is taken when entire kidney must be opened. Upper diagram to left shows plane of vascular cleavage; that to right, the needle carrying wire passing from lower calyx through upper one and thence out to the surface of kidney. After E. K. Cullen and Derge.

silver wire threaded on a curved needle is introduced into the lower posterior calyx. At the near side of the papilla the needle perforates the parenchyma, emerging on the convex border of the kidney. The capsule is then carefully split with the knife, as shown in Figure 218. This is to prevent tearing of

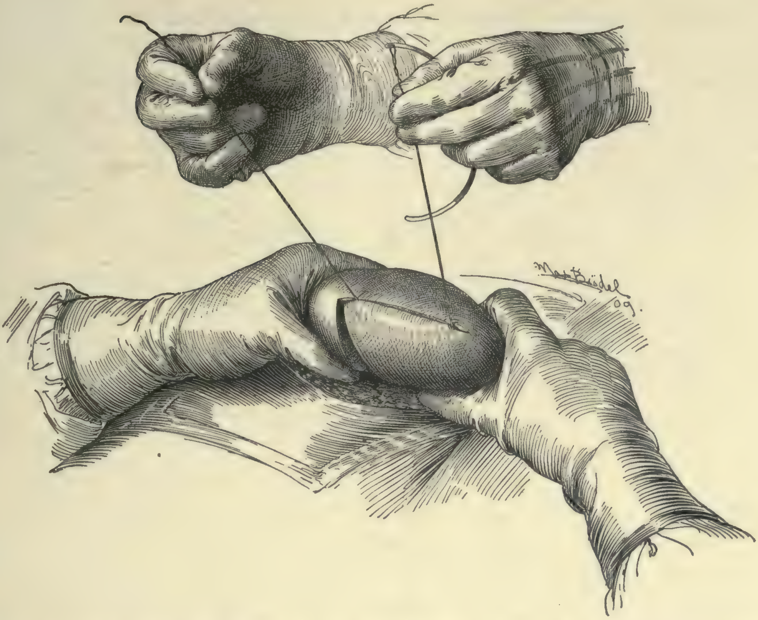


Fig. 221.—Fourth Step in Silver Wire Method of Opening Kidney. Procedure here is similar to that in second step. After E. K. Cullen and Derge.

the capsule, which is more resistant than the cortex. By a gentle see-saw motion traction is then made on the silver wire (Fig. 219).

At first a fairly strong traction is necessary to cut through the wall of the calyx and the pyramid; soon, however, the softer and less resistant cortex is encountered, when traction should be gentler so as to avoid tearing of the smaller vessels. The arteries have a firm coat of great resistance, and the wire, passing naturally in the direction of the least resistance, will seek its path between the vessels in the plane of their natural cleavage. Through such an incision a stone

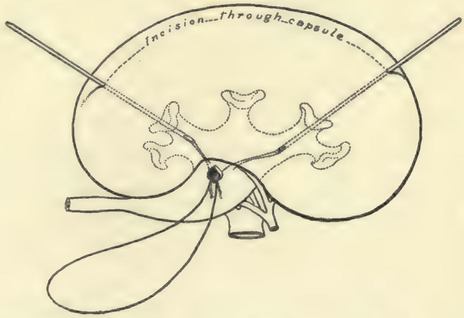


Fig. 222.—Another Procedure for Nephrotomy from Within Outwards. To insure proper placing of cutting thread it is introduced through a small opening in pelvis, as shown.

can in most cases be readily extracted, and also the rest of the kidney explored.

In order to lay the whole kidney open and render the entire pelvis and all of its calices accessible, the longitudinal incision posterior to the lateral convex border is made (Figs. 220 and 221). The curved needle is reintroduced, as shown, and brought out through the upper posterior calyx, taking care to perforate at the ventral side of the papilla. This is done in order to avoid cutting through and ripping off the papillary portion of the posterior pyramids. This saves the large collecting channels of the medulla. After having nicked the capsule, the same see-saw motion, first strong, then gentle, is made, drawing the wire out of the kidney. A flap of kidney tissue with an unimpaired arterial circulation is thus turned out and the entire pelvis exposed. The polar calices are readily explored without extending the incision further up and down, although the plane of arterial division reaches from pole to pole and a lengthening of the incision into the lower pole at least is perfectly safe. It is well, however, to preserve the venous anastomoses at the upper pole, for in this operation the outflow of the dorsal veins depends on them.

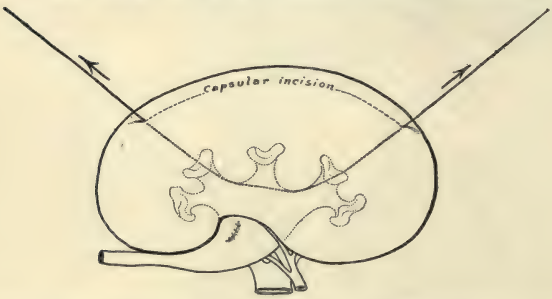


FIG. 223.—SECOND STEP OF PROCEDURE SHOWN IN LAST FIGURE.

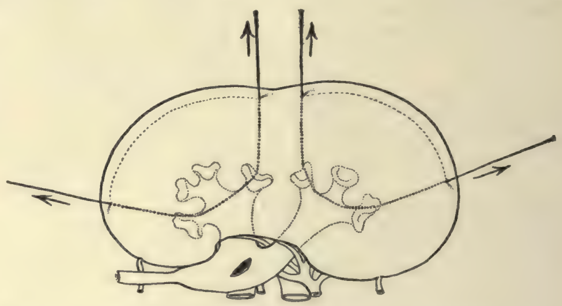


FIG. 224. — DEMONSTRATION OF ADVANTAGES OF METHOD SHOWN IN TWO PRECEDING FIGURES WHEN THE KIDNEY HAS BIFURCATED PELVIS.

The longitudinal incision may also be made direct, without the preliminary oblique incision. In order to insure exact placing of the wire inside the pelvis it is introduced with two needles, one on each end, inserted through a small opening in the renal pelvis (Figs. 222 and 223). In cases of double pelves the two separate parenchymal incisions are made, as shown in Figure 224.

Too much emphasis cannot be placed upon the necessity of firm countertraction on the kidney as the wire is being brought to the surface, as sudden or too violent traction may result in the tearing of the main renal vessels or one of its branches. As a guard against excessive venous bleeding, the pedicle may be temporarily compressed with a rubber ligature or with the fingers, as shown in Figure 217.

THE SUTURING OF THE KIDNEY.

The study of the vascularization of the kidney also teaches the principle of the most satisfactory method of closing the organ after nephrotomy. While all renal wounds, both pelvic and parenchymal, heal with great readiness, whether sutured or not, the suture usually obtains the quicker and better re-

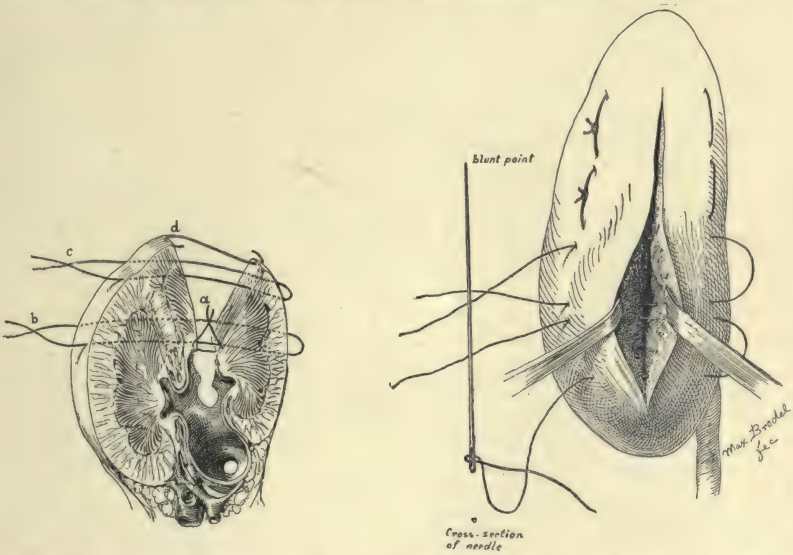


Fig. 225.—Transverse Section and Lateral View of a Kidney Showing Approximation of Cut Surfaces of Nephrotomy Wound with Mattress Sutures. Note blunt-pointed triangular-shaped needle. The mattress sutures must not be tied so tightly as to constrict kidney. Suture material should be strong, fine and readily absorbable catgut.

sult. Besides, it reduces post-operative venous hemorrhage into the pelvis to a minimum. There are cases where packing is to be preferred on account of hemorrhage, or where both suture and pack are employed.

The peculiarities of the structure of the kidney, its soft consistency, the striated character of its tissue seem to exclude single interrupted sutures, which

nearly always tear, and suggest the mattress suture as the correct type. The strong capsule especially is very valuable as an aid in affording a hold to the mattress suture, the pull being from without in, instead of the reverse.

The pelvis may be first approximated with fine catgut sutures. These should be placed between the calices and only take in the fat, the outer fibrous coat, and the muscular layers. The mucous membrane must not be included. The pelvic approximation, however, may also be dispensed with. Indeed, it is often so difficult and requires so much time that the small advantage obtained therefrom does not justify its application (Fig. 225).

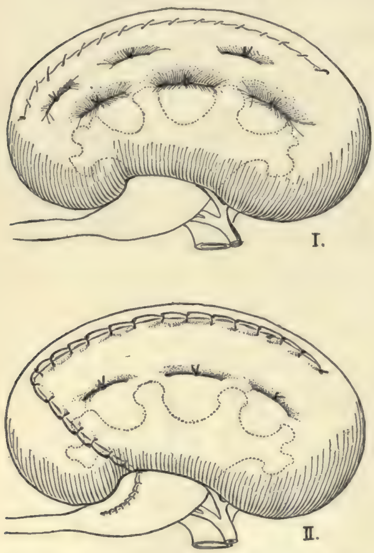


FIG. 226.—DIAGRAMS SHOWING POSITION OF SUTURES IN CLOSED NEPHROTOMY INCISION. The essential sutures are the row of mattress stitches which pass all the way through the kidney at the region of the papillæ. These must be taken to insure against post-operative venous bleeding into the pelvis. Frequently a second row of the same kind of sutures, as shown in upper picture, is of advantage. Finally, the fibrous capsule of the kidney is approximated with a continuous suture, simple or interlocking.

The second system of sutures should be catgut mattress sutures and unite the region of the papillæ. Anatomically the ideal way of placing them would be between the pyramids. The bite of the suture would then be 1½-2 cm., as the calices are approximately that distance apart; this should certainly suffice to prevent strangulation of kidney substance.

The sutures are placed with a long straight needle with a blunt point. It has to be sharp enough to push its way through the cortical and medullary substance, but blunt enough to glide past the arteries without injuring them (Fig. 225).

The purpose of this deep system of sutures is to prevent the formation of a large blood clot in the interior of the kidney and to insure quick healing of the entire renal wound. In kidneys with thick parenchyma, however, these deep sutures may be dispensed with, since the pressure of the superficial sutures suffices to approximate the cut surfaces.

The third system of catgut sutures should also be mattress sutures and be placed parallel to the second through the cortex near the base of the pyramids (Fig. 226).

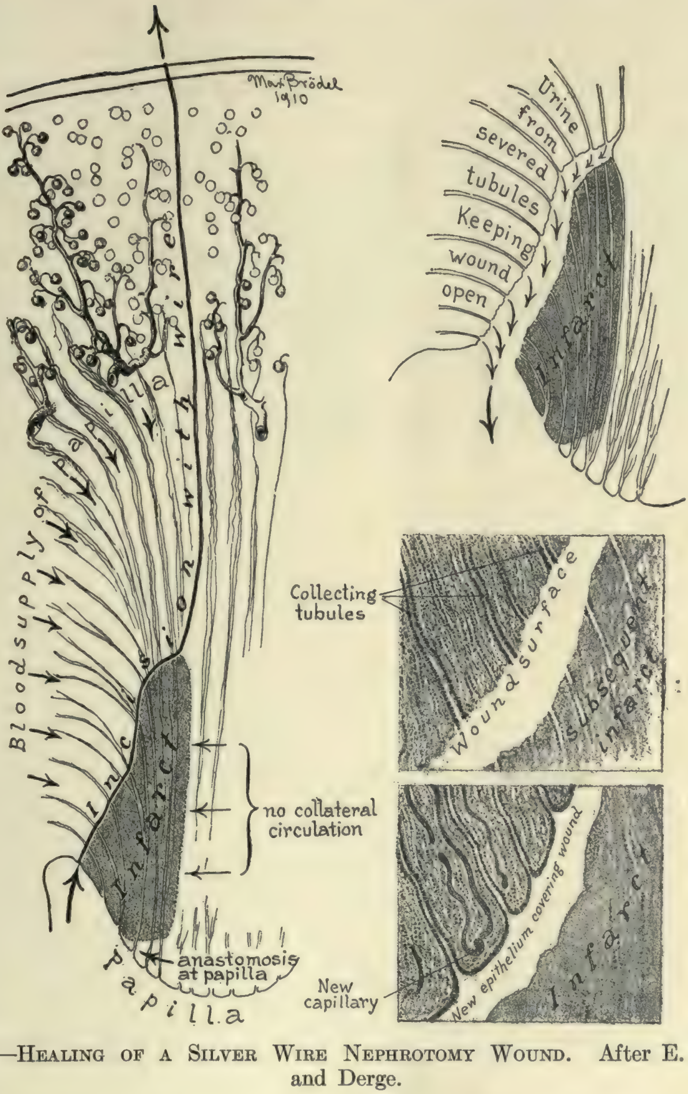


FIG. 227.—HEALING OF A SILVER WIRE NEPHROTOMY WOUND. After E. K. Cullen and Derge.

The capsule is then closed with a continuous suture (Fig. 226).

These mattress sutures stand at right angles, or nearly so, to all the main vessels. This will effectively prevent their tearing into the kidney substance which is generally encountered by passing simple interrupted sutures, especially if they are placed too superficially.

The healing of these wire incisions in dogs is rapid, as Cullen and Derge have shown. We can only surmise that such is the case in the human kidney, for there has as yet been no occasion to examine a kidney so opened. Figures

FIG. 228.—INFARCTS FOLLOWING NEPHROTOMY WOUNDS. Left, after wire method from within out; right, after knife method from without in. After E. K. Cullen and Derge.

227 and 228 show the infarct formation and the healing process in the dog's kidneys. These specimens were injected one month after operation. While the right figure shows a typical infarct caused by the knife, the left shows the scar of the wire wound. The great difference in amount of kidney parenchyma destroyed is seen at a glance. The healing of the medullary portion is of interest in so far as it shows that the papillary wound does not approximate, owing to the discharge of urine from the several ducts, which serves to keep the wound open (Fig. 227). The healing is, however, prompt in spite of that, as the epithelium of the ducts grows out and covers the wound, converting it in a sense into a new papilla (Fig. 227).

TRANSVERSE NEPHROTOMY INCISIONS.

Although the peculiarities of the kidney's vascularization seem to preclude any other method of parenchymal incision, there are others that appear satis-

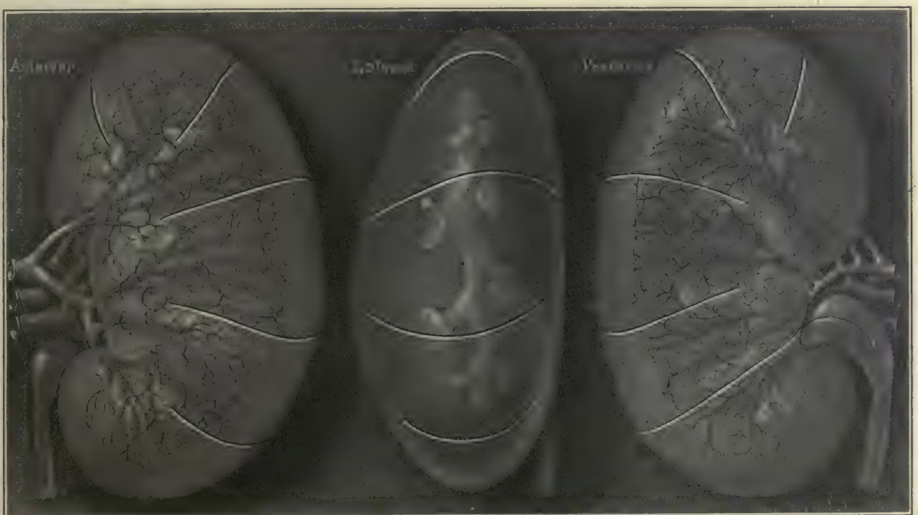


Fig. 229.—Three Views of Corrosion Preparation of Most Frequent Type of Kidney. Showing the best locations of transverse and radiating incisions.

factory in some cases. These are transverse incisions or incisions radiating from the hilum toward the lateral border (Fig. 229).

The large vascular trees anterior and posterior to the pelvis diverge from the hilum, running between the pyramids and calices. It may be assumed,

therefore, that one or several short transverse incisions through the anterior or posterior pyramids, or all the way across, would open the pelvis sufficiently to extract any moderately-sized stone through them. The calices are mapped out at the surface with comparative ease, and the columns of Bertin surrounding the pyramids may also be pretty accurately determined by following the depressions on the surface, or the stellate veins of the capsule.

Although there is a large artery running from the hilum through the central portion of the base of each pyramid, it may be avoided with the exercise of some care and the incision placed either below or above it. The lowest of these radiating incisions seems the best, since it opens the largest portions of the pelvis, no matter what its form. The wire method is also here to be preferred.

The drawbacks, however, to these transverse incisions are:

(1) Owing to the large vessels at the hilum, the incision must be short, especially on the posterior surface, and in cases where there is a large calculus it may be impossible to remove it through so small an opening.

(2) The form and extent of the pelvis are explored with great difficulty.

(3) The incision necessitates cutting of numerous, though comparatively small, arterial branches at the base of the pyramids.

CHAPTER XVI.

MOVABLE KIDNEY.

DEFINITION.

Movable kidney, nephroptosis, and floating kidney are terms applied to kidneys more than normally movable. Movable kidney and nephroptosis are synonyms. The latter word was coined by Glénard, who regarded nephroptosis as but a part of a splanchnoptosis. Similar words applied to other viscera are hepatoptosis, gastroptosis, and enteroptosis. The term "floating kidney" is reserved for very movable kidneys, and especially those which come to lie under the anterior abdominal wall, when the kidney may have a distinct mesentery or mesonephron. Formerly, especially in England, the term floating kidney was employed only in those cases where the kidney had a complete investment of peritoneum and so hung out into the abdominal cavity; this anatomical classification has now given way to the clinical one.

HISTORY.

It has long been known that the kidney occasionally becomes very movable, and some complete descriptions of autopsy findings come down to us from the middle ages. The first clinical studies of movable kidney are those of Rayer. Early recorded cases are those of François Pedemontanus in 1581, and Riolan, 1682. The latter observer states that the normal condition of the kidney is a fixed one in the flank, but that under certain conditions it becomes movable, and that stones or growths in the kidney especially favor the loosening. Rayer, in his splendid work, reports seven cases which he thoroughly studied not only from an anatomical but from the clinical standpoints of diagnosis, symptomatology, and treatment. Some of his deductions as to the nature of the condition are most interesting, and show remarkable farsightedness. He noted the condition to be much commoner than supposed, to occur more frequently in women than in men, and to affect more frequently the right kidney; he also noted pregnancies and heavy lifting to be contributory causes, pain in

the side and nausea with vomiting the commonest symptoms, and the patients usually thin and hypochondriacal; finally, he noted that, in some cases, a bandage gave relief. Dietl's masterly way, in 1864, of describing the crises of pain associated so frequently with certain types of movable kidney gave birth to the term "Dietl's crises."

The first efforts to include movable kidney under surgery occurred in 1878, when Martin did two nephrectomies for the condition. In 1881 Hahn, of Berlin, made his first attempts at suspension, and from his time up to the present there have been a vast number of operations and much ingenuity has been displayed in methods of fixation. Nevertheless, certain observers maintain movable kidney to be not a disease in itself, even going so far as to assert that it alone can give no symptoms. The chief exponent of this view is Glénard, whose earliest publications date from 1885, and who in 1900 was still maintaining movable kidney to be merely a part of a general enteroptosis. Some surgeons, notably Israel and Tuffier, also take this view, but many kidney surgeons, including Edebohls, Kelly, Goelet, and Johnson in America, Morris and Newman in England, Albarran in France, and Hahn, Schede, and others in Germany, believe that movable kidney can give rise to severe symptoms, and be effectively relieved by surgical methods.

ANATOMICAL FACTS.

Here we consider briefly the more essential facts about the normal position, mobility, and supporting structures of the kidney.

Normal Position of the Kidney.—The average normal kidney extends from the lower border of the eleventh dorsal to the upper border of the III lumbar vertebra. The upper poles of the two kidneys are 1 cm. closer to each other than the lower poles. The transverse axis of the kidney lies in a plane oblique to that of the body in such a way that the convex rounded edge of the kidney is almost as much posterior as that surface of the kidney usually described as the dorsal. The dorsal surface of the kidney lies against the eleventh and twelfth ribs; when the twelfth rib is abnormally short the kidney may lie entirely external to it. The lumbo-costal ligament, which fills in the space between the first and second lumbar vertebræ and the twelfth rib, entirely covers the posterior surface of the lower pole of the kidney. In two-thirds of all cases the right kidney is lower than the left, as first shown by Helm-Waldeyer, who attributed this fact to the pressure of the liver. Wolkow and Delitzin, who have demonstrated by plaster molds of the upper abdominal cavity that the

space where the kidney lies (the "renal niche") on the right side is less capacious than that on the left, offer this fact to explain the lower position of the right kidney. Landau attaches importance to the higher attachment of the splenic as compared with the hepatic flexure of the colon, noting also the shortness of the left renal artery and its attachment to the pancreas. All these factors are adjuvants, but, doubtless, the greatest significance belongs to the shallowness and lack of capacity of the renal niches.

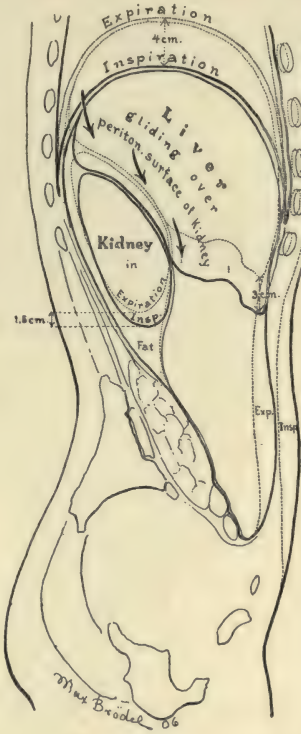


Fig. 230.—Diagrammatic Representation of Influence of Breathing on Kidney. Note how liver normally glides over it with each descensus of diaphragm. A movement downward of 1.5 cm. of the kidney may be regarded as the average amount in quiet respiration.

Mobility of the Kidney.—The older writers considered the kidney a fixed organ, and one which stood in marked contrast to the movable liver. It was Glénard who first drew general attention forcefully to the importance of respiratory mobility, now so generally recognized, while every surgeon who has operated upon a kidney has noted the up and down motion responding to each expiration and inspiration. The average mobility of the kidneys in respiration is somewhat greater in women than in men, and generally may be said to vary from 2 to 5 cm. (Fig. 230). Among the motions to which a kidney is subjected, in addition to the up and down motion, are an anterior and posterior movement, and also a rotatory one around the axis of its blood vessels. It would not seem that these two motions ever occur in normally fixed kidneys. Unless the kidney is abnormally long it should not descend below the edge of the lumbo-costal ligament on deep inspiration. On the right side the respiratory motion is transmitted to the kidney from the diaphragm through the liver; on the left side the motion is transmitted directly from diaphragm to kidney. In addition to the respiratory motion there is that dependent on posture, the kidneys being lower in the erect than in the dorsal posture. Wolkow and Delitzin have demonstrated this on autopsy for subjects hung up by the neck, and their findings, though not always paralleled in the living, are nevertheless supported here by the fact

that palpation in the erect posture points to an exactly similar condition (Fig. 231).

Supporting Structures.—Anatomical structures and forces which have been described as holding the kidney in position can conveniently come under these headings: the peritoneal coat and peritoneal folds, the fascia perirenalis or

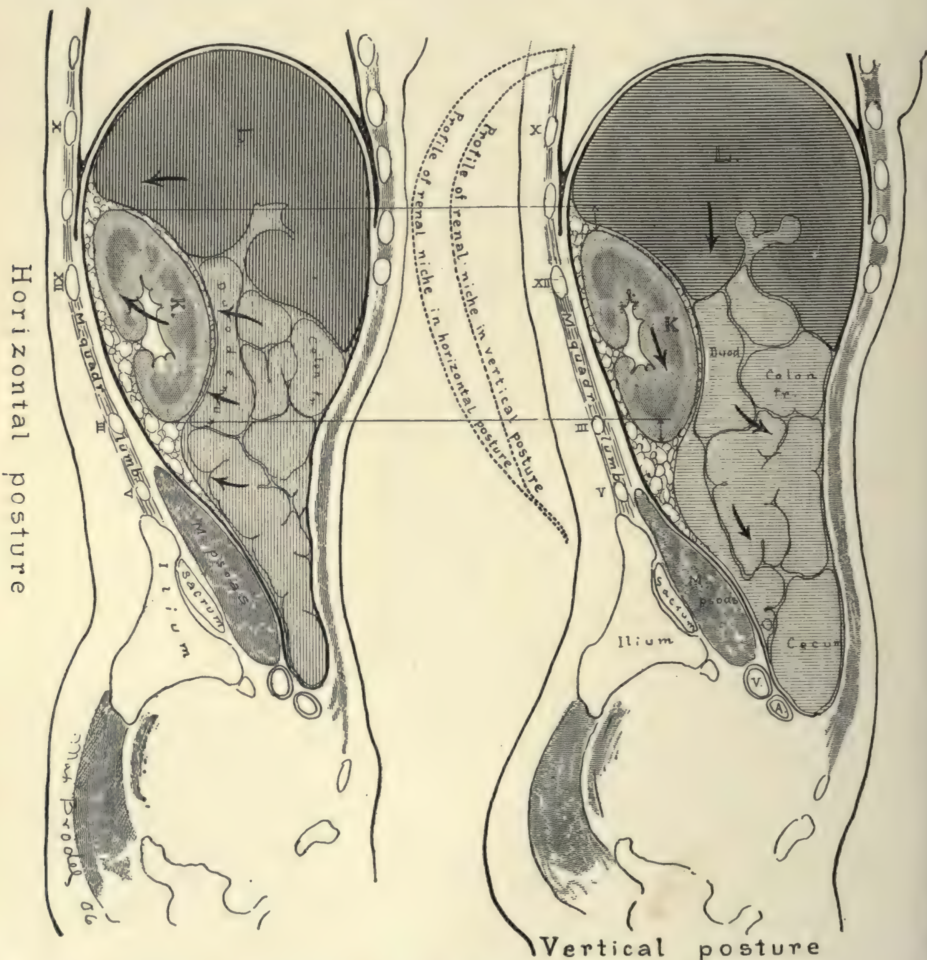


FIG. 231.—INFLUENCE OF POSTURE ON RENAL NICHES. They are much deeper in horizontal or lying-down posture than in vertical or standing-up posture. The difference between depth is indicated by dotted outlines between drawings.

Zuckerkandl's fascia, perirenal fat, vascular pedicle of the kidney, attachments to adrenal gland, attachments to the pancreas, and the intra-abdominal pressure.

(1) Peritoneal Coat and Peritoneal Folds.—Except in the case of floating kidneys, the peritoneal covering is limited to the anterior surface or face of kidney. The peritoneum is loosely attached to Gerota's capsule, and this in turn loosely attached to the fibrous capsule of kidney. In dead as well as in living subjects, it is easily shown that traction on the peritoneum slightly dislocates the kidney, and also that traction on the kidney, pulling it downward, produces crinklings and folds in the peritoneum. It is not a very unusual finding to have the peritoneum extend to the convex edge of the kidney, and very rarely the peritoneum surrounds the entire kidney when it floats in the abdominal cavity exactly like an abdominal organ. Such a complete case has not occurred in our own practice, but a number are reported in the literature. One of the most recent and interesting is that of Newman, who found such a kidney at operation and fixed it. It is not uncommon in the opposite direction to find only a part of the anterior surface directly connected with the peritoneum. There are no folds attaching the left kidney, but the peritoneum on its anterior surface is very much thicker than on the right. On the right kidney are two folds running from the upper anterior and middle border of the kidney; one extends to the duodenum, the other to the liver, the first known as the ligamentum duodeno renale, and the second as the ligamentum hepato renale. In discussing later symptoms arising from the stomach and the gall bladder, with movable right kidney, the significance of these two folds will become evident.

(2) The fascia perirenalis is a thin fibrous layer, closely resembling peritoneum, and composed of two leaves, an anterior and a posterior. The first lies between the peritoneum and the anterior surface of kidney, runs over the renal vessels, and joins with fascia of the opposite side. It is more delicate than the posterior, and also much finer over the right kidney than over the left, as Zuckerkandl first pointed out. The posterior leaf is attached to the bodies of vertebræ, to the intervertebral discs, to the psoas muscle, the walls of the renal niches, and runs over around the convex border of the kidney to fuse with anterior leaf. The two leaves fuse together above and are attached to the diaphragm. Below they do not unite, but pass off into the iliac fascia. Fibers pass from this capsule through the perirenal fat to the true capsule of the kidney, and normally the relationship is so loose that the kidney moves readily within this capsule. In the literature this capsule is described as the capsule of Gerota, Küstner, and Zuckerkandl, and the fascia perirenalis (Figs. 39, 40, and 41).

(3) The perirenal fat, or, as it is frequently called, the "fatty capsule," immediately surrounds the kidney. This fat is of a pale lemon color, sharply contrasting with the reddish subperitoneal fat, of a very soft fluid consistency, and does not appear until the tenth year of life. It varies greatly

FIG. 232.—DIAGRAMMATIC REPRESENTATION OF INFLUENCE OF ABDOMINAL WALL ON INTRA-ABDOMINAL PRESSURE AND UPON POSITION OF KIDNEYS. A, shows intact wall; B, opened abdomen, in erect posture. Approximately the same difference maintains between a normal muscular abdominal wall and a relaxed one.

in amount in the adult, but is rarely entirely absent; even in very thin people it is frequently abundant. It is particularly plentiful on the posterior face and the lower pole of the kidney and around the renal vessels, though there is much less of it on the anterior face. This fatty capsule has been aptly

described by Albarran as a "fatty atmosphere" surrounding the kidney, and its function would seem to be to afford a cushioning to prevent jarring. The kidney normally moves inside this fatty capsule, but when the motion is considerable, or when through inflammation the fatty capsule becomes very adherent to the true capsule of the kidney, it moves with the kidney (Figs. 39, 40, and 41).

(4) The Vascular Pedicle.—One of the earliest suggestions as to the cause of abnormal mobility of the kidney was an abnormal length of the renal vessels, the shortness of the renal artery on the left side being given as an explanation of the relative infrequency of abnormal mobility in that kidney.

The average length of the right renal artery is 7 cm.; of the left 5 cm. It is difficult to estimate the exact value of the vascular pedicle in supporting the kidney, but it may have a function when the kidney becomes abnormally movable; yet, as Broedel has clearly shown in his anatomical studies, the attachment of the pedicle to the kidney is evidence enough that it can normally have no particular function in holding the kidney in place. The normal mobility which occurs is not in the arc described by the blood vessels, but is an up and down motion. It is furthermore well known that kidneys with short vascular pedicles frequently have a rather marked mobility, and not uncommonly kidneys with long vascular pedicles are well fixed.

(5) Attachments of the Kidney to the Adrenal Gland (Figs. 22 and 24).—In children there is a strong attachment between the kidney and the adrenal gland, which in its turn is firmly fixed to the pillar of the diaphragm, to the upper part of the fascia perirenalis, and to the aorta by its artery. As the individual grows older this association between kidney and adrenal gland becomes less intimate, until in the adult it is not very strong. This fact is well known to the operator, who can easily separate the two, and is well demonstrated by the fact that, with the development of descensus, the kidney moves down and leaves the adrenal in its place. There is never a descensus of adrenal with the kidney.

(6) Attachments to Pancreas.—This attachment concerns the left kidney alone, and is through the connection between its blood vessel and the sheath of the pancreas. It was originally pointed out by Landau, and may possibly be of some little importance in keeping the left kidney in place.

(7) Intra-abdominal Pressure (Fig. 232).—Delitzin and Wolkow, by suspending cadavers in an upright posture, proved that there was a

certain amount of descensus of the kidneys, also, by removing the muscles from the anterior and lateral walls of the abdomen, they showed that descensus was increased and that by opening the peritoneum it reached its maximum. This argues in favor of the importance of tonicity in the abdominal muscles in keeping up a pressure within the abdomen. From the days of Rayer a relaxed abdominal wall has been considered effective in bringing about abnormal movability of the kidney, and later on, in going over the etiology we will show it to be a factor though not the principal one.

OCCURRENCE OF MOVABLE KIDNEY.

Up till 1885, when Glénard first published his findings and introduced the respiratory method of palpating for movable kidney, this condition was regarded as a rare one, a fact well illustrated by a glance at other autopsy statistics. Until his time there was very little in the way of statistics on the living. Epstein and Newman gave 16 cases of abnormally movable kidney in 14,698 autopsies; Durham gave 2 cases in 1,600 autopsies; Schultze gave 5 cases in 3,658 autopsies; Virchow gave 4 cases in 6,000 autopsies.

It is, of course, more difficult in autopsy to determine the degree of mobility, because death brings about certain changes. Nevertheless more recent autopsy statistics show the seeming rarity of movable kidney among the older pathologists to be due in part to carelessness of observation, and in part to a different view as to what constituted an abnormally movable kidney. Fischer-Benzon found 22 cases in 100 autopsies; Helm found 78 cases in 104 autopsies; Buedinger found 49 cases in 60 autopsies, and Buedinger was the last to report a series of cases.

Sex.—Abnormally movable kidney is much more common in women than in men, a fact best illustrated by the statistics. The frequency in living women is illustrated by the following table:

In	500	cases,	90	times,	Edebohls
"	276	"	85	"	Goelet
"	678	"	144	"	Otto Helmer
"	2,202	"	485	"	Glénard
"	548	"	112	"	Einhorn
"	272	"	112	"	Larabee
"	100	"	21	"	Hahn
	4,576		1,049	=	22.8 per cent.

In men:

In	392	cases,	3	times,	Skórczewsky (quoted by Morris)
"	100	"	2	"	Hahn
"	2,013	"	52	"	Glénard
"	772	"	14	"	Einhorn
	3,277		71		= 2.1 per cent.

It is thus seen that one out of every five women has a movable kidney, and only one out of every fifty men. This ratio between men and women, as well as the ratio of general occurrence, seems to hold among all races and all peoples with rather remarkable uniformity. In addition to the greater frequency in women, it is to be noted that the right kidney is more frequently movable than both kidneys; both kidneys more frequently movable than the left alone. The right kidney has been estimated to be abnormally movable from twelve to twenty times as frequently as the left.

In our own 245 cases the right kidney alone was movable 177 times; both kidneys 43 times; left alone 25 times. R. B. Larabee (112 cases), right kidney palpable alone 98 times; both kidneys 14 times; left alone not once. Goelet (85 cases), right kidney palpable in 84 cases; left alone only once. Stifler (100 cases), right alone movable 75 times; both kidneys 10 times; left alone 15 times.

It must, however, be borne in mind that abnormal mobility in two kidneys is frequently very different on the two sides, e. g., there may be a very movable right kidney and a left kidney which is barely palpable. The reverse of this condition is also shown:

Miss F. R., Gyn. No. 12,220, operated upon by Kelly, July 7th, 1905. This patient had suffered for 8 years with pain in the left side and back, in the form of attacks corresponding to typical Dietl's crises. Left kidney in this case extremely mobile, right merely palpable. Injection of left kidney showed that its pelvis held 6 c. c. of urine, and that the attack of pain brought on was exactly similar to that of which she complained. Urine normal. The kidney was suspended to the twelfth rib, in the method to be described. This patient seen in June, 1907, and has since remained perfectly well.

There are two other questions as to the occurrence of movable kidney: one the frequency as to age, the other the frequency of coöccurring ptoses of other abdominal organs.

Age.—It is generally stated that movable kidney makes its appearance most commonly in the middle periods of life. Morris says that more than half

the cases occur between thirty and forty. In 242 of our own 245 cases where the movable kidneys were producing marked symptoms, and where in most cases operations were required to relieve these symptoms, the cases were portioned according to age as follows:

Between	15	and	20,	5	cases
	20	"	30,	94	"
	30	"	40,	95	"
	40	"	50,	40	"
	50	"	60,	7	"
over	60			1	case

Between the ages of twenty-five and thirty-five there were 125 cases, or more than one-half of the entire series. This age, however, does not represent the age of onset of symptoms. The average duration of symptoms in our cases before operation was five years, and, deducting these five years, more than half the cases made their first appearance or gave their earliest symptoms between the ages of twenty and thirty. Our youngest case as to the onset of symptoms was fifteen years, the oldest sixty. The development of the first symptoms so frequently at a certain period of life is not easy to explain. It may be that personal activity at this period, the fact of menstrual congestion, and the fact that it is the most active period of child-bearing have something to do with this greater frequency of onset.

It is frequently asked: Does movable kidney occur in children? This question can be answered in the affirmative, although in the majority of cases no marked symptoms are produced. Stillé has reported several cases in infants; Rosenthal observed twenty-six cases in young girls; Hahn, who examined twenty-five boys between two and nine years, did not find a single case of movable kidney, while in twenty-five girls belonging to the same station in life he found one case. Blum examined one hundred and six children between the ages of three and fifteen and found thirty-seven cases of movable kidney, twenty-nine in girls, eight in boys. Most of his cases were chlorotic and rather poorly nourished. J. A. Abt reports five cases, three in boys, two in girls, in which there were marked symptoms produced by movable kidney, they having dragging pains in the side and attacks of Dietl's colic, just as in adults. In four of the five cases the right kidney alone was movable, in one case both kidneys.

Concurrence of Abnormally Movable Kidney and Ptoses of Other Organs.—Rayer long ago pointed out that some of these subjects were of a lean body

form and inclined to a melancholic disposition. Glénard, in his studies of dyspeptics at Vichy, so frequently found descensus of the various abdominal organs with movable kidney that he has taken the view that movable kidney is practically always a part of a splanchnoptosis, dependent upon a congenitally weak condition of the supporting structures of the abdominal viscera. If movable kidney occur alone, he maintains it will soon be followed by movability of the other organs, and these frequently become movable before the kidney. That such association occurs in patients who frequent clinics like that at Vichy, is beyond question, but it certainly does not exist in the surgical types of movable kidney, that is, those producing marked symptoms, such as we report in our series. Most surgeons take this same view; the most marked exceptions being Tuffier and Israel. Albarran says such an association is rare; Morris, that in ninety-eight cases he can count the cases of general enteroptosis on the fingers of his hand. In our own cases we found movable kidney alone 149 times; movable kidney with retroflexion of uterus and no other ptoses 65 times; movable kidney with descensus of stomach, 23 times. From this it is evident that the commonest associated ptosis with movable kidney is retroflexion of the uterus. This, however, is not necessarily present, and one occasionally meets with a uterus in good position, yet a ptosis of nearly all the other organs.

ETIOLOGY.

Speculation has been rife, since the first discovery that the kidney is sometimes very movable, as to the cause or causes of this condition. Those who argue *a priori* assume at once that the condition is either congenital or acquired, and, that if acquired, its development must either depend upon an abnormal weakness of supporting structures or, if support is normal, the forces tending to dislodge the kidney must be excessive. The problem to the practical man familiar with actual cases is further modified, because his views regarding these factors must be reconciled with certain known facts as to the occurrence of abnormal mobility. Why is movable kidney many times more common in women than in men; why is the right kidney much more frequently movable than the left; and why is the greater frequency of movable kidney more evident at certain periods of life than at others? In giving an adequate explanation he will find many causes have been suggested, and much reiteration in the literature.

Now, taking the question of congenital and acquired movable kidney: In the most cases abnormal mobility is acquired. We should say that in every one

of our own this was established. Nevertheless, occurrence of movable kidney in very young children, and the fact that there are kidneys with a complete investment of peritoneum, show that in certain cases the patient is probably born with this abnormality. But setting aside rare cases, what causes have been set up and defended by various observers? (1) Tumors and stones of the kidney; (2) pregnancy and childbirth; (3) rapid absorption of perirenal fat; (4) tight lacing; (5) peculiar body form; (6) trauma; (7) menstruation; (8) congenital predisposition; (9) dragging of the cecum; (10) stomach dilatation.

Tumors and Stones of the Kidney.—Riolan, 1682, thought these the commonest of all causes, though this opinion has little or no bearing on the subject as at present understood. The infrequency of such conditions in proportion to the common occurrence of movable kidney prove this, though we have met with both stone and tubercular kidneys which were movable. Quite recently we had a very movable form of the latter. Such findings, however, are exceptional, for usually the inflammatory processes which occur around these kidneys quickly anchor them. Hydronephrosis, which occurs not infrequently with movable kidney, is to be considered as secondary rather than primary.

Pregnancy and Labor.—One of the first things to suggest itself to the doctor looking for a cause of movable kidney, and knowing its greater frequency in women than in men, is that it depends in some way on pregnancy and labor. Several explanations of this opinion have been given: (1) violent expulsive efforts of labor have been assumed to dislocate the kidney; (2) distention of the abdominal walls during pregnancy has been supposed to result in a relaxation afterward leading to lowering of the intra-abdominal pressure, thus favoring the development of movable kidney; (3) it is also urged that while some cases develop immediately after labor, others are merely started by it, and the earliest symptoms may develop months later. That these causes are sometimes operative is beyond question. Out of our own, nine date the onset of symptoms either from pregnancy or labor. Of these, six occurred immediately after labor, four of these six presenting long, thin bodies, while two were fat and well nourished. The following case, taken at random, illustrates the history of such a patient:

Mrs. B. R., age 26, Gyn. 11,233, date April 25, 1904; complaint, dull aching pain in right side, continuous, occasionally acute attacks. The patient had always been a well, strong, and active woman, two years married, and had her first child fourteen months ago. There was nothing unusual in the labor, but on getting out of bed at the end of fourteen days she began having

the dull ache in the right loin. In this case the right kidney was found to be very movable; 10 c. c. of fluid injected into its pelvis reproduced the pain. All the other abdominal organs were in good position. We suspended the kidney to the twelfth rib, and she has remained entirely free from pain.

It is not infrequent for a kidney which has been giving only moderate symptoms to develop rather violent ones during pregnancy. We have had eight cases, in two of which the symptoms seemed to have first made their appearance during this period. Perhaps increased congestion during pregnancy has something to do with the development, but the mere fact that a certain number of cases develop symptoms after labor favors the view that certain cases may start at this time, only later developing into the symptomatic stage. But that pregnancy and labor are only minor factors in producing movable kidney is evidenced by the fact that, out of our two hundred and forty-five cases, only ninety-five had had children. Moreover, clinicians observe every day the large number of women with relaxed abdominal walls, due to multiple pregnancies, where the kidneys are well fixed in place. These findings, corroborated by other sources, contrast markedly with some of the older statistics; for example, Landau found that forty out of forty-two patients were in parous women, and Senator, twenty out of twenty-five.

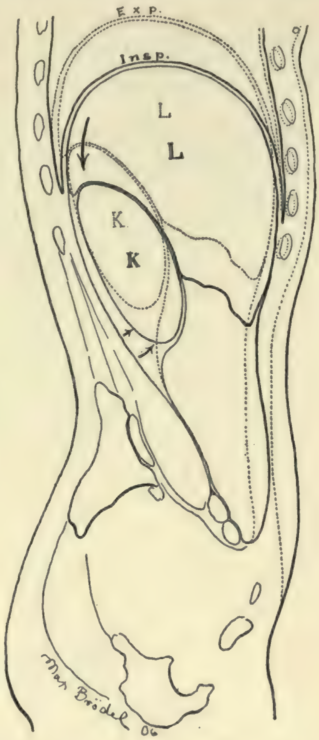


Fig. 233.—Diagrammatic Representation of Absence of Fatty Wedge at the Upper Pole of the Kidney, Allowing the Liver to Descend and Partially Pocket the Kidney. This interferes with the normal gliding motion and transfers a larger amount of the descensus of the liver upon the kidney. Note how lower pole of kidney pushes ventrally, tending to form mesonephron.

Rapid Absorption of Fat.—Recall again the fact of the kidney being surrounded by a fatty capsule, for the disappearance of this, and especially its rapid disappearance, has been held to be a cause of movable kidney. Some of the most movable kidneys in my experience have been associated with extensive fatty capsules; yet, on the other hand, it is not unusual to find a well-fixed kidney with little or no fatty capsule. Up till the tenth year of life children

do not have one. In our own cases, thirty-eight gave a history of definite loss of weight. In all gastro-intestinal symptoms were marked. It was, of course, difficult to distinguish as to which was primary, the movable kidney or loss of fat. The indicative results in many of them show kidney mobility to be the primary trouble (Fig. 233).

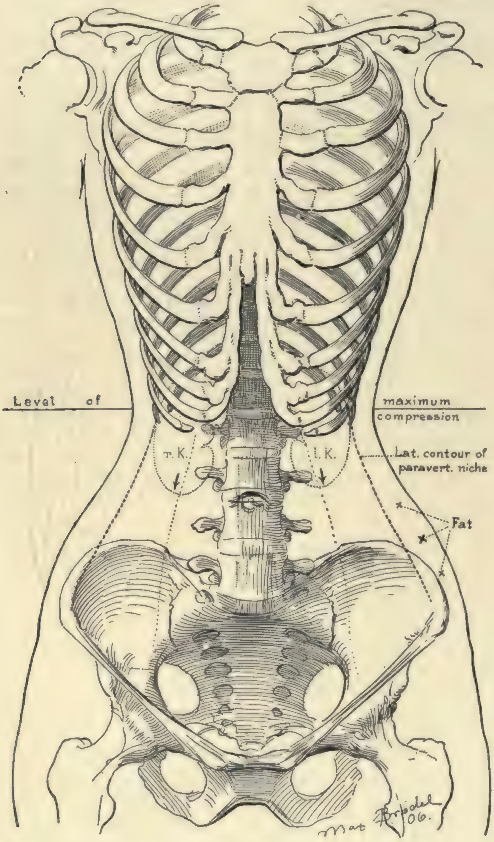


FIG. 234.—SKELETON SHOWING INFLUENCE OF TIGHT-LACING ON THE THORAX AND INDIRECTLY ON THE KIDNEYS. Note how accumulation of fat over crest of ilium makes lacing at a low level impossible. The level of maximum compression is, therefore, relatively high. This leads to a destruction of the paravertebral niches, rendering them incapable of sheltering the kidney.

Here is an excellent example: Mrs. Z. H., Gyn. No. 8,627, April 2, 1901, age 28. This patient, rather well built, mother of two children, came in complaining of attacks of nausea and vomiting, and a dull pain in the right side. Stated that she had lost forty pounds in weight. As no disease beyond movable kidney was discoverable, we fixed this, and, during the next year, she gained fifty pounds, and has remained well ever since.

Seeing the importance of fat in supporting the kidney, the condition of patients suffering with movable kidney in regard to nourishment is interesting. Out of our cases, sixty-three were well nourished, seventy-eight markedly thin, and one hundred and four neither very thin nor very robust. It would seem from all this that the loss of fat has but slight bearing on the production of movable kidney.

Tight Lacing. — Cruvielhier considered corsets, worn by almost all civilized women, to be the most potent factor in causing movable kidney, and since then tight lacing has been pointed to by many authors as a

principal cause, the wearing of constricting waistbands and heavy skirts being also incriminated. As nearly all women who wear modern dress use corsets and to a large extent tight clothes, the estimation of this factor is difficult. We have not found any unusual proportion of noticeable tight lacing, and the women themselves came from every position in life. Movable kidney might

FIG. 235.—POSTERIOR VIEW OF MALE BODY SHOWING ALTERATIONS IN SIZE AND FORM OF RENAL NICHES OCCASIONED BY POSTURE. Figures show paravertebral niches from behind; posterior abdominal wall being removed. These outlines are obtained by making plaster casts of niches. Picture to left shows appearance in horizontal (lying-down posture); that to the right in vertical, standing-up posture. Note capacious pear-shaped form of renal niches, which are evidently well suited to hold kidney and shelter it from the forces tending to displace it; K shows position of kidney. (Based on Delitzin and Wolkow.)

be assumed to be more common among fashionable women than others. We do not think this is so. The investigations of Becher and Lennhoff, also those of Trekaki, are important in this connection. The two first found six cases of movable kidney out of twenty-four Samoan women whom they examined, or one in every four. Now these women do not wear corsets or constricting clothes of any kind, and are rather notable for their athletic abilities. Trekaki, too, states that two-fifths of all Egyptian women have movable kidneys, yet among them there is no tight lacing or corsets.

It is quite conceivable, as Küster has urged, that a constricting band at the level of the tenth rib might diminish the space of the lower chest and push the kidney out of place, and Wurrmann has worked out a most interesting

and ingenious scheme as to how this is brought about, showing how the liver is first pushed out of place and tilted back, while it, in turn, pushes the right kidney out of place. Certain it is that a well fitting corset at the level of the twelfth rib or lower would rather have a tendency to hold the kidney in place than to dislocate it. We are not impressed with the importance of tight lacing in producing movable kidney, though we do not defend a pernicious habit, and one so likely to produce injurious effects of other kinds, not, however, properly to be considered in this place (Fig. 234).

Fig. 236.—Posterior View of Female Body (Elderly) Showing Alterations in Size and Form of Renal Niches Occasioned by Posture. Left horizontal, right vertical. In vertical posture, the lower ends of niches are wider and upper shallower than in horizontal posture. The differences on the right side are more marked than on the left. Note how, in the female, the niches become cylindrical and tend to be wider below than above, or than they are in the male. (Based on Delitzin and Wolkow.)

Peculiar Body Form.—It has long been noted that certain types of women seem to have movable kidney, and the first scientific investigators to show the importance of body form in leading to development of movable kidney were M. M. Wolkow and S. N. Delitzin, who made plaster casts of the upper abdominal cavity and showed that there was a niche on either side in which the kidney lies. In a normal individual these niches are pear-shaped, with the smaller end pointing downward. In a subject of movable kidney they are widely dilated at their lower ends and much smaller than normal, thus leading to a cylindrical shape of the niche, or, in the most extreme cases, of a funnel shape with the large end of the funnel downward. The depth and shape of the niches also were shown to vary with posture. The niches are most capacious,

the lower ends narrowest with the subject in the dorsal posture, most shallow and with widest lower ends in the erect posture. The eleventh and twelfth ribs are the structures most important in determining the shape of these niches, and the authors demonstrate by specimens that in men the niches are always pear-shaped, in women frequently cylindrical, and the right niche

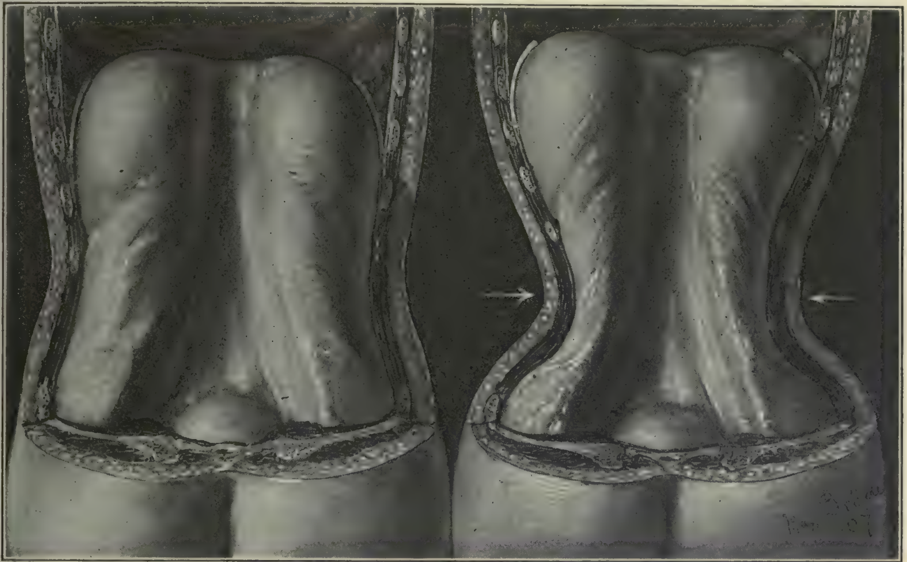


FIG. 237.—PLASTER OF PARIS CASTS OF ABDOMINAL CAVITY OF GIRL 18 YEARS OF AGE The posterior wall of the body is removed showing the form of the paravertebral niches, in the figure to the left without corsets, to the right, with corsets. Mobility of right kidney in this case was 4.5 cm. Note shallowness of niches in left figure. Also note depressions on casts caused by XI and XII ribs. The action of the corsets in the right-hand figure causes a marked narrowing of the niches below the level of the kidneys, and may thus form a support for them. (Based on Delitzin and Wolkow.)

nearly always shallower and more cylindrical than the left. When both niches are shallow and cylindrical-shaped they state both kidneys to be movable. The most extreme cases met with were in subjects suffering with general enteroptosis (Figs. 235, 236, 237, 238 and 239).

Becher and Lennhoff were the first to carry out investigations on the living patient in reference to this anatomical peculiarity, and as a result conclude that people with long narrow chests and lumbar regions have movable kidneys, and those with short broad trunks, as a rule, have them well fixed. They devised a simple method of measuring and deduced an index: First, the distance was taken in centimeters from the sternal notch to the upper margin of

the symphysis pubis, and this measurement divided by the shortest circumference of the abdomen, the result being multiplied by one hundred. In their cases the resulting figures varied from sixty-three to ninety-five centimeters. They state that, with an index above seventy-five, the kidneys are likely to be movable; if it is below, the probability is they are well fixed. M. L. Harris, of Chicago, is a warm advocate of the importance of body form, and has confirmed the findings of Becher and Lennhoff on one hundred and twenty-six women. He places the patient in the dorsal posture, divides the length in centimeters from the sternal notch to the symphysis by the mean of two circumferences, one taken at the level of the tenth rib and the other at the lower end of the sternum, each at the end of deep expiration. From seventy-seven to seventy-eight represents the median point with him, and corresponds to the seventy-five of Becher and Lennhoff. In the one hundred and twenty-six cases examined, seventy-one had movable kidneys, and fifty-five had not. The index in all positive cases was above seventy-seven. He therefore discards all other causes of movable kidney, and considers body form the one important factor. Dr. W. F. Griffith, formerly on the gynecological staff at the Johns Hopkins Hospital, found the average index in fifty-one women without movable kidney was 71.1, and that in thirty-one women with movable kidney 76.5. He considers as movable only those cases in which the entire lower half of the kidney can be palpated, and does not include those in which the lower pole can merely be touched. In twenty-four men the average index is 67; he found only one movable kidney in twenty-four men examined.

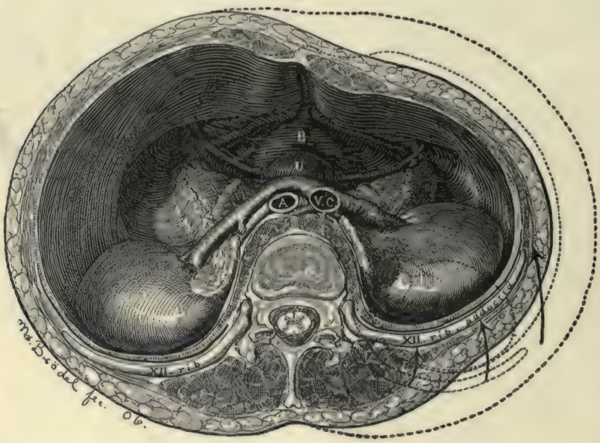
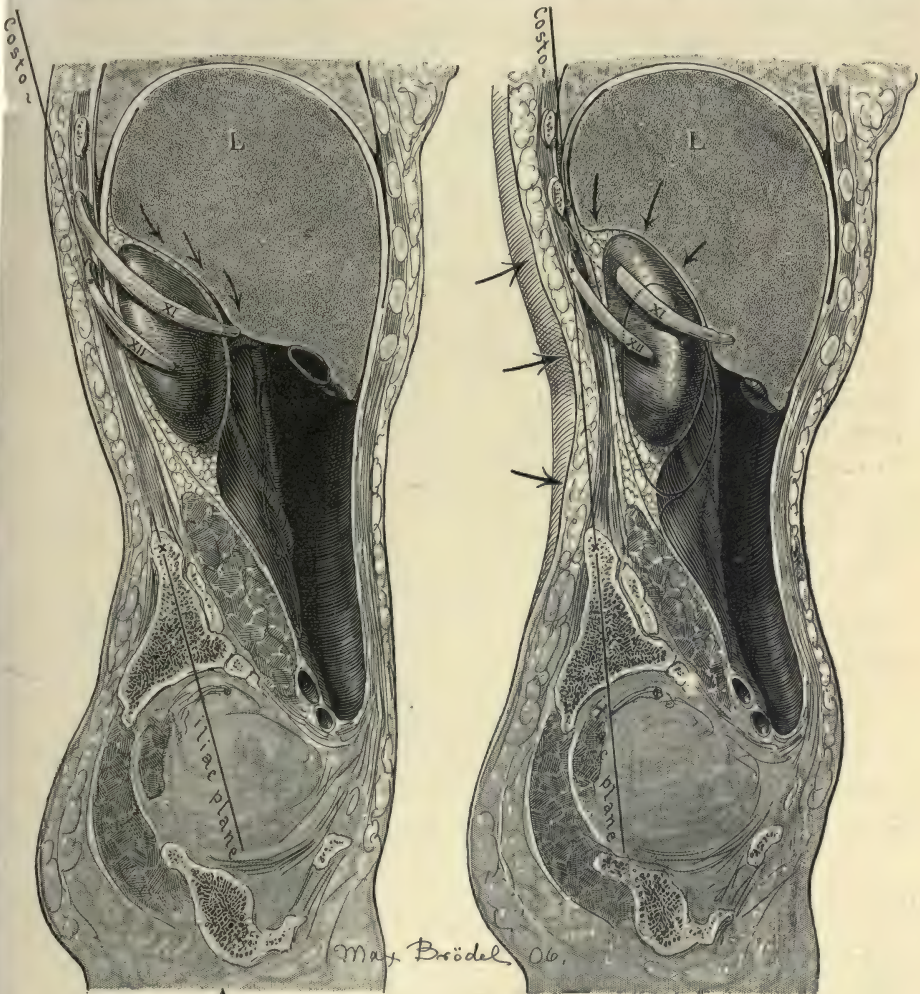


Fig. 238.—Transverse Section of Trunk Between Eleventh and Twelfth Rib. The left side shows normal abdominal cavity, capacious renal niche. The right side shows effect of lacing in reducing abdominal cavity and in adducting ribs with resultant decrease in capacity of renal niche.

Body form clearly has an important bearing in predisposition to movable kidney, but we cannot go so far as to take the stand of those authors who

assert that with a cylindrical-shaped chest movable kidney is always present, and that with a well-shaped one it never occurs, for it is not uncommon to find



A B

FIG. 239.—LONGITUDINAL SECTIONS OF TRUNK SHOWING EFFECT OF ADDUCTION OF ELEVENTH AND TWELFTH RIBS UPON POSITIONS OF LIVER AND KIDNEY. The line showing direction of costo-iliac plane indicates how in picture to the left with a normal body kidney stays in place; picture to the right, shows influence of narrowing and destruction of the renal niche through adduction of ribs. Note how adduction pushes upper pole of kidney ventrally, subjecting kidney to full pressure of liver; its descensus with inspiration is indicated.

women with narrow, long chests and well-fixed kidneys or with well-shaped chests yet very movable kidneys. Only recently we had a case of this kind in the hospital.

Mrs. J. S., age 50, complained of pain in the right side of abdomen in the form of attacks. The pelvic organs, stomach, and left kidney were in good position, the right kidney extremely movable. Injection of this kidney reproduced the attack. The patient was a moderately well-nourished woman; had had her trouble for years; she had a well-formed chest. The measurements taken according to Becher and Lennhoff were 51 and 77, which gave an index of 66. The kidney in this case was movable to the third degree.

Trauma.—Here we include cases where accidents, such as falls, blows, and the like, have caused movable kidney, dividing the traumatic causes into two classes: the acute and chronic. Among the acute are falls either upon the feet or upon the side, blows in the lumbar region, and violent sudden depressions of the diaphragm. Among the chronic may be mentioned excessive straining, as sometimes occurs in cases of marked constipation; likewise the straining due to heavy lifting; the often-repeated excessive contraction of the diaphragm which occurs in chronic pulmonary conditions, causing repeated coughing, and the continuous jolting of various exercises, of which horseback-riding furnishes a good example.

M. J. Harris, of Chicago, reports an interesting series of forty-one cases where the patients have attributed their trouble to an acute injury. Studying these cases carefully in reference to the shape of the body, he found that all of them had the peculiar body form described by Wolkow and Delitzin, and for this reason concluded trauma alone to be of secondary importance, as in a normal person it would not cause movable kidney. Küster takes a somewhat similar stand and states that in women, falls are liable to produce movable kidney, whereas in men the kidney itself is injured but not dislocated.

Thirteen patients in our case list attributed their trouble to injury. In nine the injury was due to a fall; in four to lifting unusually heavy weights. Among these nine, five stated that symptoms made their onset after a fall upon the feet, and four after a fall upon the back or side. Among the four cases following heavy lifting one was from lifting a wash-boiler, and another a trunk, and one, a very intelligent trained nurse, ascribed her symptoms to lifting a patient. Taking these cases in reference to body form our notes state that three of them were well formed and well nourished.

Payle has recorded a case of his own where dislocation of the kidney followed immediately upon a severe massage of the lumbar region, and C. O. Baker one where the development of a movable kidney was the result of a sea

voyage, the patient suffering from nausea and vomiting for some days. In none of our own cases could we attribute the movable kidney to chronic cough-

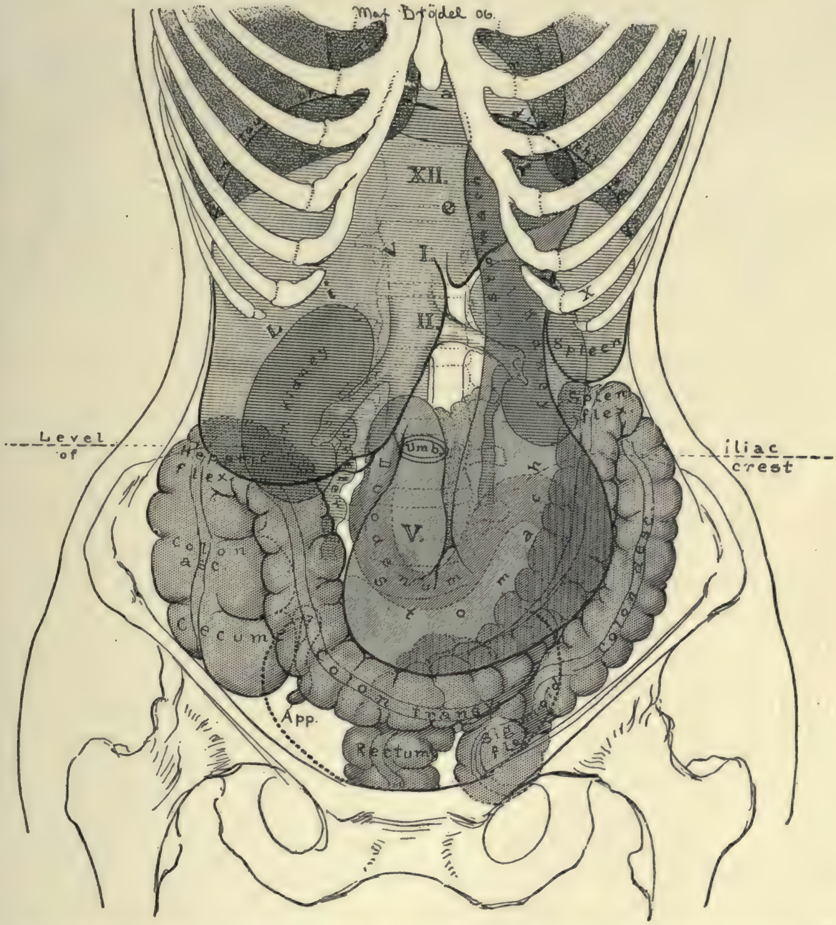


FIG. 240.—SCHEMATIC REPRESENTATION OF POSITION OF KIDNEYS AND ABDOMINAL VISCERA IN CASE OF ENTEROPTOSIS. Composite picture based on a study of nearly a hundred bismuth X-ray plates of Dr. Henry K. Pancoast, of Philadelphia. The most characteristic and frequent positions of each organ have been taken. Note the narrowness of the lower thorax, which was a common characteristic of all cases.

ing or to injury from horse riding. Many of them were chronically constipated. We are convinced that a considerable number of patients developed movable kidney as a result of traumata. The majority are people with the body

form of Wolkow and Delitzin. But cases occur where there is no such predisposing cause.

The influence of the liver and the diaphragm on the causation of movable kidney is well shown in Figures 233, 241, and 242.

Menstruation.—The increased weight of the kidney as a result of the congestion at the menstrual period has been ascribed as predisposing to the development of abnormal mobility, and Becquet has particularly urged this point. Morris ("Diseases of the Kidney and Ureter") reports a case where the kidney was seen to increase markedly in size during the menstrual period, and it is a fact that most persons who have pain in a movable kidney suffer more at the menstrual period, while many other patients give histories of attacks of pain at this period alone. But pain in any locality in the body is liable to be exaggerated at the menstrual period, and it would not seem that menstruation could have any great influence in leading to mobility, though it doubtless has considerable importance in exaggerating symptoms.

Congenital Predisposition.—It is not uncommon to find several cases of movable kidney in a family, which is not surprising, taken in connection with body form. Glénard considers the subjects of movable kidney to have a congenital weakness of all structures supporting the abdominal viscera, and contends that movable kidney is a part of a splanchnoptosis. In the series of two hundred and forty-five cases, which form the basis of this chapter, we had only twenty-seven cases of marked splanchnoptosis associated with movable kidney, which, of course, from the particular surgical character of cases that we are dealing with, speaks against the importance of an hereditary factor. Albarran was a firm adherent to the importance of hereditary factors, and thinks a large majority of the patients show signs of physical degeneration. Stillé was the first to call attention to the frequency of floating tenth rib in patients having movable kidneys. Inheritance does unquestionably play a part, but not so important a one as some authors state. Many of our patients were perfectly normal physically and came of healthy, strong families.

The association of a general enteroptosis with movable kidney is shown in Figure 240.

Dragging of the Cecum.—In certain cases the attachments between the colon and the right kidney are sufficient to cause a pulling down of the kidney when the cecum is drawn down, a fact taken by some authors to mean that movable kidney is due frequently to the dragging down of the cecum. The strongest advocate of this view is Longyear, who bases his method of treating movable kidney largely upon his belief in the etiological importance of this fact. Rayer refers to a case of Velpeau, who found a right kidney pulled down by

a cecum which was an inguinal hernia. Certainly in the majority of cases there is no dragging down of the kidney by the cecum, and, while we cannot absolutely exclude it, it would not seem to be a frequent cause of movable right kidney. At any rate, in most cases traction on the colon or cecum does not dislocate the kidney.

FIG. 241.—ROTATION OF LIVER AROUND A TRANSVERSE AXIS, AS INDICATED BY DIAGRAM. With each descensus of diaphragm liver rotates about this axis, does not push kidney down, but may form a support forcing it into its niche, as indicated by arrows.

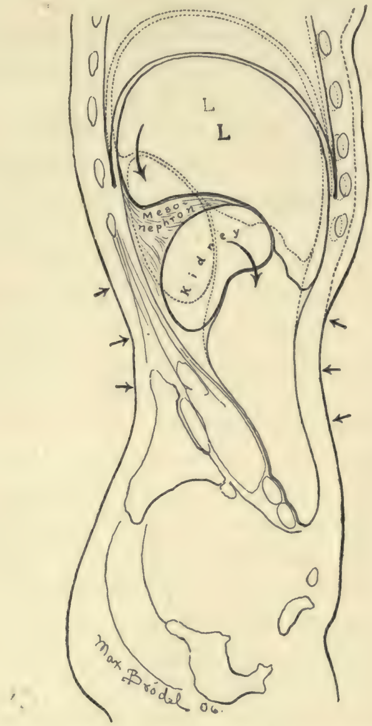


FIG. 242.—DIAGRAMMATIC REPRESENTATION OF FORMATION OF MESONEPHRON AT UPPER POLE IN FLOATING KIDNEY.

Dilatation of the Stomach.—The occurrence of dilated stomach with movable right kidney was first described by Bartells, and Litten considers that the former frequently leads to the latter, as in forty cases of dilated stomach he found the right kidney movable twenty-two times. In our own cases we found markedly dilated stomach with movable right kidney twenty-four times, yet we

do not consider the coöccurrence of the two very frequent. It seems far more probable that the dilated stomach is secondary to the abnormal kidney mobility, than that the kidney is made movable by a dilated stomach.

Movable kidney then seems to depend on a number of predisposing and active causes. The predisposing causes are especially body form and laxness of the supporting structures of the kidney. The actual causes are various acute and chronic traumata.

PATHOLOGY.

Until recently, abnormal mobility of the kidney was considered a predisposing cause to many serious renal diseases, and even of late years articles bearing such titles as "The Importance of Movable Kidney in Producing Cancers of the Kidney," "In Producing Tuberculosis of the Kidney," etc., are found. We do not regard a movable kidney as more liable to infection or tumor formation than a kidney which is not so. In the majority of cases a very movable kidney does not seem to be doing quite the same amount of renal work as its fellow, but even this is by no means without exception, and by comparing the urines from the two sides the movable kidney is sometimes found to be secreting more than the fixed one.

Later on, when we speak of hydronephrosis, we will show movable kidneys as a frequent cause of this condition. Excluding from our calculation cases of marked hydronephrosis and taking only those where mobility of the kidney was the principal complaint, we found, in sixty-one cases, eight showing beginning hydronephrosis. The pelves of these kidneys held from 20 to 50 c. c. of fluid, as shown by injection through a renal catheter. It is certain, of course, that the majority of movable kidneys do not develop hydronephrosis, as shown by the great frequency of movable kidney and the comparative rarity of hydronephrosis. Under hydronephrosis we will give in detail the mechanism by which a movable kidney becomes hydronephrotic. Personally we are inclined to confirm Albarran's observation that quite a large percentage of movable kidneys show fetal lobulations, but an unusual movable kidney with a perfectly normal form is quite frequently seen. The vascular pedicle in movable kidneys is longer on the average than in those which are well fixed. Edebohls has noted a frequent congestion of the appendix associated with movable right kidney due to pressure on the vessels supplying the appendix. We are not impressed with the occurrence of this condition, and think it necessary to bear in mind that as congestion of the appendix is a very common disease, and

movable kidney likewise very common, their coöccurrence in a number of cases has very little significance.

Certain authors, Goelet, for instance, of New York, have urged that a large number of patients suffering with seeming congestion of the pelvic organs really have a movable kidney which presses on the ovarian veins and thus produces the congestion below. It is perfectly conceivable that a dislocation of the kidney would cause such a condition, which would be especially marked on the left side, as the ovarian vein here empties directly into the renal vein. It is rather unusual to find a marked varicose condition of the ovarian without a coöccurring condition of the uterine veins, and, therefore, the finding of such a condition must be taken with all these facts in mind. We do not ourselves consider any particular association between congestion of the pelvic organs and movable kidney to exist. From what has been said about the influence of menstruation on the kidney, it is, of course, readily seen that congestive conditions of the pelvic organs might act to some degree in causing symptoms in a kidney already movable.

That dilatation of the stomach may occur through pressure or traction of a right movable kidney upon the duodenum is in certain cases unquestionable. Morris ("Diseases of the Kidney and Ureter") quotes Franks and McAllister, who observed in one case that pulling down of the right kidney almost completely occluded the duodenum. From studies of our cases at the Johns Hopkins Hospital with particular reference to gastric symptoms, it seems that this traction or pressure is comparatively common, although rarely to the degree described by Franks and McAllister. As the attacks come on most frequently with the patient in an upright posture, it would seem that the traction effect is probably of more importance than direct pressure. The importance of the latter thought is illustrated by the fact that many of the patients are unable to lie on the left side. Such a posture would bring the right kidney directly on the duodenum. Traction could, of course, be exerted through the duodenorenale fold of peritoneum already described. It is possible that the excessive development of this fold accounts for these conditions, or, more likely, they may be due to the fact that the peritoneum is more closely attached to the anterior surface of the kidney in some cases than in others. A great number of movable right kidneys exert no traction at all on this part of the peritoneum. In certain cases movable right kidney causes obstruction of the common bile duct, and the mechanism of this action is most likely traction, as most of the cases clear up readily when put flat on their backs in bed, and develop when the patients are active. There is never complete obstruction, and in our experience kidneys which are not exces-

sively movable are more liable to cause this condition than those which are movable to the third degree.

SYMPTOMATOLOGY.

Abnormally movable kidneys do not usually give rise to marked symptoms, and, like most organ displacements, cases associated with symptoms, while conforming to certain types, often show marked variations in clinical appearances. The cases may be divided into those associated with local pain in the loin, pronounced stomach and intestinal symptoms, marked nervous symptoms, symptoms from the bladder, gall bladder symptoms, and with symptoms of unusual character. It must not be imagined, however, that any single case will conform to one type alone. In the individual case all of them may be present, and the relative importance of the different groups of symptoms varies with the individual; also their intensity at different times in the same individual, and in different individuals. It is not uncommon for one set of symptoms so completely to occupy the patient's mind that others are not even noted, and only discovered by inquiry on the part of the physician. Gastric symptoms with movable right kidney are, for example, not uncommon, but though in many cases, at first questioning, the complaint may appear entirely gastric, we find that careful taking of the history and tactful inquiry will discover in almost every case some local symptoms associated with the kidney itself.

But on being told that certain movable kidneys do not cause symptoms the natural question arises: how frequently do such cases occur, and are the people perfectly healthy? Well, there is no question that many healthy, active people have abnormally movable kidneys giving no symptoms. Brewer found in two hundred women eleven movable kidneys, and in only one of these cases could he discover any symptoms attributable to the kidneys. Combining the cases from the clinic at the Johns Hopkins Hospital and from our private hospital, there are about seventeen thousand cases in all, and only two hundred and forty-five cases of movable kidney. Taking the statistics as to its occurrence in women as twenty per cent., there should have been in this group of seventeen thousand patients, thirty-four hundred cases. Of course, many of these patients had movable kidneys that were giving symptoms, but a rough estimate shows that only one case in ten actually gives rise to marked disturbance, the degree of mobility being no indication as to the amount or severity of symptoms. The cases which have no disturbances may be only

slightly movable or movable to the third degree, and it is noteworthy that frequently the most severe symptoms are associated with kidneys which are very slightly movable. This is readily understood in view of the fact that gastric symptoms are due to mechanical effects of pull on the duodenum, and a kidney moving entirely within its fatty capsule is more likely to be so placed as to cause a kinking of the ureter, than one in which the entire capsule moves with the kidney. Edebohls has especially urged this point, and considers that from 4 to 10 cm. represents the highest degree of pain. We have repeatedly operated on patients by suspension and effected cures where the kidney was barely palpable on bimanual examination.

Pain.—This, when associated with movable kidney, can roughly be divided into two kinds: that which is characterized by being rather dull but almost continuous, and that which comes in the form of attacks. Many theories have been advanced to explain the pain occasioned by some movable kidneys. Knapp considers it due to pressure on the nerve trunks of the lumbar plexus. Edebohls thinks it largely due to pressure on the solar plexus. Great importance has been attached by some to dragging on the peritoneum, on the vascular pedicle, or on the common bile duct (in a few cases); and dragging on a twisted ureter has long been considered a very important cause.

Whatever the actual cause of pain, in most cases forceful injection of the pelvis of the kidney with fluid, driven in through the catheterized ureter, will reproduce it. This is particularly true of all cases with attacks, and, as a matter of fact, even the cases without attacks show such variation in intensity of pain that injection serves to enable the patient to recognize that it is the same she complains of. The dragging pain is usually present in the back and side and is often relieved by the patient lying flat on her back. The upright posture and exercise especially aggravate it, while many of the patients complain of not being able to lie on the side opposite to that of the movable kidney. The pain is often increased during menstrual periods; always increased during pregnancy, especially the early months; frequently increased by constipation; and not uncommonly by severe mental exertion. In most cases the pain is located posteriorly in the loin and the region immediately in front of the kidney, with occasionally pain rather low down, near McBurney's point, or over the hip. In patients with continuous dull aches, radiation of this aching is not common. We have found it only nine times out of one hundred and thirty-six patients: in two cases to the hip, in two along the course of the ureter, in two to the shoulder-blade, and in one each to the leg, brim of pelvis, and across abdomen, respectively. We always find dragging, dull pains commoner than acute

attacks, and in our series one hundred and thirty-six patients complained simply of dull, continuous aching; forty-one patients had acute attacks of pain, but between attacks were comfortable; and thirty-three had both dragging pain and attacks. Just as in the case of the dragging pain, so in the attack there is, as a rule, little radiation. In the seventy-four cases where attacks occurred, radiation was noted in only eleven; in four of these the pain ran down the ureter, in three down into the leg, in one to the groin, in one across to the opposite kidney, and in two to the shoulder. The intensity of the attacks varied greatly in the same individual, and also varied between one individual and another. In some instances the patients were able to keep about; in others pain was so severe that they were violently nauseated, had vomiting and profuse sweats, and often a little fever, and were compelled to go to bed. The duration of the pain varied as well as its intensity. An attack can vary in length from a few minutes to two days, though, of course, the most violent pain is usually of short duration. The frequency as to its occurrence is also variable, depending upon the individual; some patients complaining of recurrence every day or two, others speaking of months elapsing between the individual attacks. It is often difficult for the patient to accurately determine what brings these on, but, in the majority of cases, they are convinced that exercise, straining, lifting, and horseback-riding are most potent causes. In some patients the attacks seem to follow eating heavy meals, many complain that they occur just before or just at the beginning of the menstrual periods. Subsequent to a severe attack, it is not uncommon for the patient to pass a large quantity of urine. We have never met with a case of extreme shock from an attack of pain, but such are on record, and, according to Morris, even deaths have been reported.

The anatomical cause of such attacks is as difficult of explanation as that of ordinary pain, but in some cases it is doubtless due to a twisting or a kinking of the ureter. In each of the eight cases where we met with a beginning hydronephrosis the pain was in the form of attacks, the trouble being relieved by suspension of the kidney. A great many cases, however, with definite attacks of pain evidence no hydronephrosis, and we must consider the twisting of the renal pedicle to be the cause of pain. In cases with jaundice the attacks of pain may be those of hepatic colic. Newman and Albarran have reported interesting observations, where at operation they discovered twisting of the ureter, and Edebohls was the first to advise manipulative reposition of kidney to terminate such an attack.

As one can readily see, with such a variation in the symptoms the general conduct of patients varies immensely; some are able to keep about and do a

good deal of exercise and active work; others complain that they are unable to carry on any active occupation in life; and the more severe cases are almost bedridden on account of the pain.

Gastro-intestinal Symptoms.—Most of the symptoms which arise from the gastro-intestinal tract and which can be ascribed to movable kidney originate in the stomach. It is not uncommon to find cases of marked constipation, and others where there is an association of enteroptosis and marked neurasthenia, also mucous colitis, diarrhea, etc.; but, as we have never succeeded in relieving these symptoms by simply fixing the kidney, we do not definitely ascribe them to movable kidney. The fact that marked gastric disturbance can be associated with movable kidney has long been recognized and attributed to various causes. That most of them are of nerve origin, either through the sympathetic system or reflexly through the central system, is an opinion generally held.

A second cause of great importance in this connection is enteroptosis. In a few cases the mechanical action upon the stomach by pressure upon the duodenum has been noted. From analysis and study of our own cases, we conclude that the great majority of patients suffering from gastric symptoms develop these as a result of mechanical action on the stomach by the right kidney, such conclusion being reached by weighing the following facts: Out of one hundred and seventy-seven cases where the right kidney alone was movable sixty-eight cases had marked stomach symptoms. The right kidney in each of these sixty-eight patients was suspended; forty-six of the sixty-eight were relieved of gastric disturbance, thirteen of the sixty-eight have been lost sight of. Of the seven remaining cases where failure was noted, only three were uncomplicated; two had pelvic inflammatory trouble and chronic appendicitis, one had retroflexion of the uterus, and one marked descensus of the stomach, a stomach operation being done as well as suspension of kidney. Out of twenty-five with left kidney alone movable, only four had gastric symptoms; two of these have been lost sight of, and the other two, while relieved of the pain in the left kidney, received no benefit from the operation, as far as gastric symptoms were concerned. Out of forty-three cases with both kidneys movable, twenty-two presented stomach symptoms, but three of these had nothing except slight nausea and vomiting during violent attacks of pain. Therefore, excluding these, we have nineteen cases on our list. Of these, twelve had both kidneys suspended, eight were relieved of stomach symptoms, three were lost sight of, and one was not benefited. In four cases where we suspended the right kidney alone, two were relieved, one was lost sight of, and one was unrelieved. Where both kidneys were movable, we suspended the left alone three times,

doing this because all the pain was in the left side. Two of these cases were failures, and one was lost sight of.

The frequency of gastric symptoms, due to gastric disorders, to chronic appendicitis, and other causes, makes the results as far as suspension of right kidney is concerned very suggestive, because it is so clearly shown that the left kidney has practically nothing to do with production of gastric symptoms, for in uncomplicated left kidney these rarely occur, and no relief is afforded by suspending the left kidney. Of course, in this series of cases it must be borne in mind that exhaustive diagnosis was made in each case to exclude actual stomach disease, or disease of any other organ than the kidney operated upon, and we do not for a moment urge that the same percentage of gastric symptoms exists among all classes of patients with the two conditions.

It is difficult to gauge the importance of nervous influences in producing gastric disorders with movable kidney. Out of a total of ninety-seven cases with gastric symptoms, thirty-six showed likewise marked nervous, and sixty-one no nervous symptoms. It is quite as easy to assume that these depended on the pain, and the gastric disturbance, as that the symptoms from the stomach were of nervous origin. The importance of enteroptosis with descensus of the stomach in producing gastric symptoms does not seem very great. Out of ninety-seven cases with gastric disturbance, only fifteen were associated with enteroptosis. Nevertheless, these fifteen cases occurred out of twenty-three cases where gastroptosis was present.

That the great majority of movable kidneys associated with stomach symptoms are not associated with gastroptosis is obvious, but in cases where gastroptosis is present a higher percentage show stomach symptoms. Out of fifteen cases with gastroptosis, many of which were also associated with double movable kidney, six were cured of their digestive complaint by operation on the kidney, five were unrelieved, and four lost sight of.

In nearly all patients treated by us for gastric trouble by fixation of movable kidneys there have been local symptoms from the kidney. In three cases these were nothing more than a sense of a foreign body moving in the abdomen. We operated in only five cases, where there was no local disturbance whatever; in three of these the operation failed, in two it was largely successful, although one of them still complained a little.

Now this inclines us to the opinion that gastric disturbance due to movable kidney is nearly always associated with local symptoms in the kidney, remembering, however, that gastric symptoms may be very pronounced and local ones but slight. The character of the former varies; sometimes there is chronic indigestion, sometimes attacks of nausea and vomiting. Just as with

the pain, these two types are frequently associated. The attacks of nausea often set in after severe exercise or jolting, but not uncommonly after eating heavily. One of our own cases had them particularly in the morning; another, in addition to nausea and vomiting, had that peculiar craving for food so frequently associated with pregnancy. Most of such cases also showed constipation and flatulency.

A markedly dilated stomach was not apparent where gastric symptoms were present, although perhaps in many of them lesser degrees of dilatation existed and escaped our clinical methods of examination. Bartells and Küstner were the first to urge that dilated stomach could result from pressure on the duodenum by a movable right kidney, and Litten (page 447) in an early observation of these cases thought the movable kidney due to the dilated stomach.

Nervous Symptoms.—Most varied types are not infrequent with movable kidney, nervousness in one form or another being complained of by seventy-eight out of our two hundred and forty-five cases. In the great majority of cases simply extreme nervousness was complained of; but inability to carry on severe or fatiguing work; insomnia; migranic headaches; various forms of neuralgia, have all been described; and marked cases of hysteria, in which paralyses, anesthesias, cataleptic attacks, and other major manifestations of hysteria show themselves, are also met with. These extreme symptoms nearly always evidence marked neurotic tendencies, both personal and hereditary.

Nervous symptoms associated with movable kidney, in many cases depend seemingly upon the irritation of a congenitally weak nervous system, and not infrequently the sense of having a movable kidney and feeling it, with the vague fears which arise in the patient's mind from knowing of such a condition, aggravate and bring about these symptoms. Rugi and Fiori have suggested that mobility of the kidney in some way alters its internal secretion, and attribute the nervousness to a form of intoxication. As nothing of the internal secretion is known, and these cases are not particularly pronounced, this view, while interesting, has no evidence. *We do not believe a movable kidney which gives no local or gastric symptoms ever leads to marked nervousness.* Personally we have had no experience in treating nervous patients without local symptoms by fixing the kidney. Out of our seventy-eight cases with marked nervousness, localized pain was present in every case, and in forty-six there were also gastric symptoms.

The nervous dominated the other symptoms in twenty-six cases. In twelve of this group, relief was afforded by operation; in four, while the other symptoms were relieved, the nervousness was as marked as ever; in four there was

failure to give any relief at all, while six cases have been lost sight of. It would seem, therefore, that in almost 50 per cent. of the cases the nervousness depended on abnormal mobility of the kidney. These figures correspond closely to those of Albarran, who reports that 50 per cent. of his cases were cured of nervousness by fixation of the kidney. In no case has nervousness ever been relieved and the local symptoms remained unrelieved. This would seem to show that in many cases of movable kidney the concurrent nervous symptoms were dependent upon the pain and the psychic influence exerted upon the patient by a knowledge of the condition.

Bladder Symptoms.—With the exception of a slight increase in frequency of micturition during the attacks of Dietl's crises, there is no bladder disturbance from abnormally movable kidneys, and the presence of vesical symptoms positively indicates some other trouble, either of kidney or bladder origin. Nevertheless, it is not infrequent to find in patients with movable kidney symptoms such as burning and frequency of micturition, and in our own series we have had forty-four cases of bladder disturbance. A careful study at once suggests the trouble which occasions the frequency of micturition or pain to be something else than movable kidney. Although we had more unmarried than married women in our list, thirty-two of the forty-four cases occurred in the latter. Among the other twelve cases one was in a man and eleven in unmarried women. In five there was marked enteroptosis and the symptoms consisted merely of slightly increased frequency in micturition. One other case had retroflexion of the uterus, another pelvic inflammatory disease, a third albumin and casts, being apparently a case of essential nephralgia. So it is practically evident that under close inspection all cases that give bladder symptoms are complicated ones. Apolant and Landau have recorded cases of marked polyuria associated with movable kidney. Under Physical Examination we will mention the occurrence of abnormal elements in the urine, as histories of blood or pus in it are not to be associated with the condition of movable kidney.

Symptoms from the Gall Bladder and Liver.—In very exceptional cases of movable kidney attacks of pain occur which in every way simulate those of hepatic colic, such attacks being usually associated with jaundice. The location of pain in the attacks is always near the middle line, the radiation is toward the shoulder-blade, and injection of the kidney pelvis will not reproduce the pain. The jaundice associated with movable kidney is usually of short duration and not of great intensity. Litten, one of the first to report a case of this kind, says that in his case, a woman of thirty-seven years old, he considered the jaundice due to pressure on the common bile duct by the right kidney.

Landau, again, first held that traction on the duodenum caused interference with the output of the bile from the common duct and led to attacks of jaundice and hepatic colic. Gallant comes next, observing patients of this kind, as a rule, to be quickly relieved by rest in bed, which would seem to confirm Landau's view. The assumption that something unusual must be present to lead to the interference with the flow of bile by movable right kidney is warranted by the comparative rarity of the condition, and, no doubt, causes similar to those which we described under gastric symptoms enter into these cases. Numerous cases are on record, while more are recorded every year. We would briefly recall here the cases of T. E. Gordon, Schultze-Wellinghausen, Mueller-Harneck, J. T. McClagan, Sir Frederick Treves, W. H. White, Gallant, C. M. Mullen, and Martin Tinker. As for our own, there have been six in which either a history of attacks of jaundice was obtained or in which jaundice was found at the time of operation. The first of this kind to come under our observation was a young woman of twenty-three. She had attacks of pain in the right side, associated with nausea and vomiting and mild jaundice. She was operated upon May, 1896, the right kidney being suspended to the quadratus lumborum muscle, and she made an uneventful recovery from the operation and has since been free from attacks. In two of the six cases, in addition to a movable right kidney, there were gall stones in the gall bladder; both of these patients had marked jaundice. Believing that the stones in the gall bladder could not cause the jaundice, we explored the common duct in each case from end to end without finding any stones. In one of these patients operated upon at our sanatorium about a year ago, we particularly observed the right kidney, which was large and lay directly pressing against the gall duct. In this case we suspended the kidney through the same incision that was made to explore the gall passages. In the other case the kidney was suspended after turning the patient over and going in from the back. Both of these patients have remained well, so far as their symptoms are concerned. In another case, an unmarried woman of thirty, there had been one attack of severe jaundice, but a number of attacks of pain in the kidney, a pain reproduced by injecting the kidney. We suspended the kidney in this case without exploring the gall ducts, as there was no jaundice at the time of operation, and she has been well now for two years. This may, of course, have been simply a catarrhal jaundice. The most recent case of our series was in an unmarried woman of forty-eight, a school teacher. She had had repeated attacks of pain in the right side, associated with mild jaundice, and at the time of operation was slightly jaundiced. With the pain there was always marked gastric disturbance. Injection of kidney produced a pain different from that complained of, and we made a

diagnosis of gall stones. An incision over the gall bladder, May 16th, 1906, disclosed a perfectly normal gall bladder and ducts, but a very movable right kidney, which could be pushed up directly against the ducts, easily causing some obstruction. In this case the stomach was also somewhat dilated. We suspended the right kidney through the loin and did a pyloroplasty on the stomach. For two years now the patient has been perfectly free from attacks. The importance of these jaundice cases, one can readily see, is great, both to the renal surgeon and to those particularly occupied with the gall bladder and its ducts.

Symptoms from the Pelvic Organs.—Leucorrhea, dysmenorrhea, and other symptoms arising from the pelvic organs in association with movable kidney have impressed some authors by their frequency. Goelet particularly urged the importance of this association, stating that 75 per cent. of his patients had symptoms indicative of pelvic congestion. The concurrence of retroflexed uterus and movable kidney is frequent, and the frequency of other pelvic disorders enough to add to the number of patients having both movable kidney and pelvic disease. With the exception of dysmenorrhea, which consists rather of an increase in kidney pain during the period, a study of our patients gives no evidence of any association between pelvic disease and movable kidney, so its occurrence must, in our opinion, be considered accidental. Schede has an interesting case where first one ovary was removed, then the other, and finally the uterus, without relief, success being attained only by the suspension of a very movable kidney.

Appendical Symptoms.—That right movable kidney and appendicitis frequently coexist is not to be questioned, and only by most careful diagnosis can one distinguish sometimes between the two. In most cases where we have found a coexistence of the two conditions the patients have had two distinct kinds of pain; the one was reproduced by injecting the pelvis of the kidney, the other was not. Whenever there is any question as to the diagnosis, Edebohls has been much impressed with the frequency of movable right kidney and chronic appendicitis, the appendicitis being consequent to a congestion of the appendical veins following pressure of the kidney on the mesenteric veins, the kidney carrying these veins and pressing them against the head of the pancreas. His teaching, which required the removal of the appendix as well as suspension of the kidney, should be followed. Very occasionally we have met with patients where removal of the appendix has not given relief, and we have had later to suspend the kidney. Exactly the reverse condition is sometimes met with, but careful examination and consideration of all symptoms usually sharply differentiates between the two, and we have rarely found it necessary

to remove the appendix in order to give the patients relief in those cases on which we base our study.

Unusual Symptoms.—Among those due to movable kidney may be put edema of the leg, vomiting of blood, severe headaches, salivation, neuralgia, and asthma. Rayer records an autopsy case where edema of the right leg was apparently due to movable right kidney, and Landau one somewhat similar. The literature has many cases where the most potent symptom has been violent attacks of headache, and typical cases of this kind have been reported by F. B. Gamgee, H. J. Barling, and Stuart Tidey. The basis for attributing the symptoms to movable kidney is that, on fixing the kidney, headaches which have resisted all other forms of treatment have disappeared, and in my own series there have been three cases where they have been relieved by suspension of the kidney. These patients all had local symptoms associated with the kidney as well as headaches. So unusual are such cases that we briefly give them:

Mrs. E. T., age 34, Gyn. No. 2,795, May 23d, 1894. Patient dated her trouble from an attack of typhoid fever 2 yrs. ago. Immediately after this she had attacks of pain in the right side associated with nausea, vomiting, and a constant ache on top of head. Examination showed a pale, frail-looking woman weighing ninety pounds, with a very movable right kidney, pressure upon which reproduced the pain, and a retroflexed uterus. We suspended the right kidney and the uterus. She left the hospital relieved of her symptoms, and 12 years later writes that she has never had any further trouble, and within a year after operation had regained a weight of 140 pounds, never lost since. The headache in this case was a constant dull one in the top of head.

Miss E. M., age 40, Gyn. No. 8,795, May 25th, 1901. She had had for 5 years dragging pains in the right side and headaches when on feet. When lying down had neither headaches nor dragging pains. In addition to the movable right kidney there was a retroflexed uterus. We suspended both, and the patient has remained well since.

The third case gave exactly the same physical findings. The patient had marked attacks of headache, associated with attacks of pain in the kidney. Both relieved by suspension of kidney.

The menstrual period usually shows an exaggeration of pain in a movable kidney, and in three cases the pain was only present at that time. In all three there was a concurrent retroflexion of uterus, and in each we suspended both uterus and kidneys, and in all the symptoms were relieved.

A most interesting phenomenon, probably reflex nervous in character, is seen in cases where attacks referable to the lungs are really due to the movable

kidney. D. A. Newman has reported two cases of recurrent asthma completely relieved by suspension of kidney, and we give another very interesting one:

Miss E. K., Gyn. No. 10,326, age 42, March 13, 1903. This patient was originally admitted to the Johns Hopkins Hospital Oct., 1896, for movable right kidney, which was suspended. The kidney became loose again and in April, 1902, she had several gall stones removed. After this operation she was well until November, 1902, when she had an attack of pain in the right kidney region. Immediately following this, the patient had violent attacks of coughing of such severity as to occasion great distress, and these persisted almost continuously up till the time of admission to the hospital. Physical examination showed no disease whatever of the lungs, and the patient was convinced that cough was due to the movable kidney. Dr. T. S. Cullen suspended the kidney. Immediately after operation the cough ceased, and since that time she has remained perfectly well. She was last seen August, 1907, and considers that the cough was due to the kidney trouble.

Albert Raube again has reported cases from Küster's clinic where lightning pains resembling tabes were present, all relieved by suspension of kidney. Bocchi also relieved a case where the chief complaint was marked salivation in the morning.

C. M. Moullin tells of a woman, forty-two years old, who had violent attacks of epigastric pain, associated with nausea and vomiting of blood, attacks which had been occurring for two years. A diagnosis of gastric ulcer was made and the patient kept in bed for some days preparatory to an operation on the stomach, but the symptoms disappeared. As the right kidney was very movable, Dr. Moullin came to the conclusion that it might be causing the attacks. A suspension of the right kidney gave relief of the symptoms, so he concludes from this they were due to the movable kidney.

Two cases simulating pancreatic diabetes were, S. Tilden Brown reports, relieved also by suspension.

With the exception of the conditions described by Brown and Moullin, all these symptoms would seem to be of nervous origin, and the infrequency of their occurrence the most notable fact with regard to them.

PHYSICAL EXAMINATION AND DIAGNOSIS OF MOVABLE KIDNEY.

Two distinct problems present themselves in connection with diagnosis: to demonstrate first that the kidney is movable, and, second, that the symptoms are due to such a condition. The first question is in most cases determinable through

physical examination, i. e., palpation of the kidney. In some cases the question arises whether a movable body felt in the abdomen is really the kidney, and only by becoming expert at palpation is the differential diagnosis made. The second question is complicated, because movable kidney often does not give symptoms, and its most characteristic symptoms may be simulated in other abdominal diseases. A careful consideration of the facts of the history and certain special methods of artificially reproducing the symptoms, notably by injecting the pelvis of the kidney through its catheterized ureter, will insure a solution.

How to Determine a Movable Kidney.—The most frequent kind of kidney mobility is an up and down motion. There are others, however, capable of producing very disagreeable symptoms, such as the forward and backward motions and the rotary motion around the vascular pedicle. It being once known that movable kidney could give rise to symptoms, the question arose in all minds just what degree of mobility marked the overstepping of the normal. Some authors urge that mere palpability of a kidney does not constitute mobility, others are equally ardent in contending that a normal kidney cannot be felt at all. Movable kidney is a disease only when it gives symptoms, and one cannot set down any rules as to what degree constitutes disease. In many cases extremely movable kidneys give no symptoms, in others kidneys which are very little movable give most marked symptoms. A kidney which becomes twisted on its pedicle or one which produces a kink in the ureter as soon as it starts to move may both be so little movable that they are not palpable at all by bimanual examination. Such cases are not common, and in the vast majority a kidney which gives symptoms can be felt. For our own part we have found only one where the kidney was not palpable at all, and in a thin patient. In many the kidney which was giving symptoms was only slightly movable, and abundant cases are on record in the literature where mobility was not such as to be made out by palpation. Morris reports some, also Albarran. Edebohls pointed out that from 8 to 10 c. c. of mobility presents the greatest amount of pain, and that kidneys more movable are less likely to cause pain. We are accustomed to the view that a kidney which is palpable is more movable than the normal one, basing this view on the fact that there are many more cases where pain is complained of in movable kidneys which can just be palpated than in cases where the kidney cannot be palpated at all. The classification introduced by Glénard, which divides kidney mobility into three degrees, is a useful clinical one and has not been supplanted by the many additional classifications made since his original communication. His degrees of mobility are: (1) when the lower pole of the kidney can just be felt on deep inspiration;

(2) when the kidney can be caught near its middle during deep inspiration and held so as to prevent its receding upward during the following expiration; (3) when the entire kidney can be grasped, the hand pushed above the upper pole. In mobility of the third degree observation shows that the kidney displays very little tendency to go back into its normal place on expiration (Fig. 243).

Methods of Palpation.—(1) THE DORSAL METHOD.—This is the oldest method and one most commonly used. The patient lies flat on her back with the knees drawn up, the legs flexed on the abdomen, in order to relax the abdominal muscles. The fingers of the left hand are placed in the flank underneath the twelfth rib, and the angle between this rib and the erector-spinæ muscles. The thumb of the left hand is pressed into the lateral wall of the flank; the fingers of the right hand are placed over the kidney on the abdominal wall. The patient is asked to take a deep breath. If the kidney is only slightly movable, at the beginning of expiration it can be felt as a smooth, rounded body by the left hand, slipping up into the abdomen. When it is quite movable it can be grasped between the two hands, and if very movable it can be pushed low down in the side. It is usually convenient when examining the left kidney to reverse the position of the hands as described. The characteristic points about the kidney are that it is usually more plainly felt by the posterior hand than the anterior. One can also make out in the more movable cases the kidney outline. It is also possible in some cases to feel the pulsating vessels at

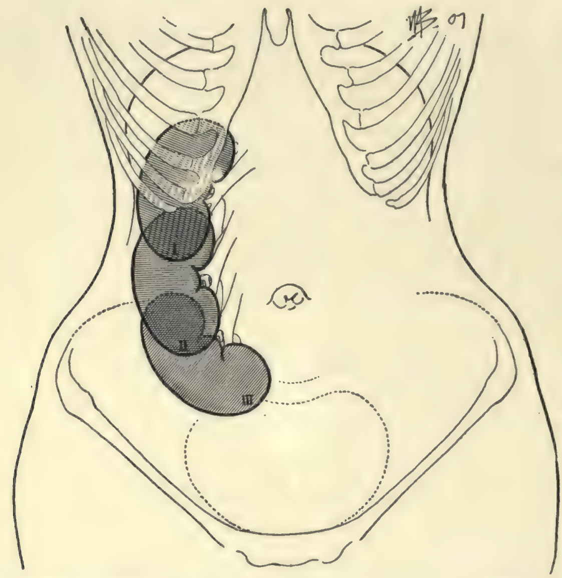


FIG. 243.—DIAGRAMMATIC REPRESENTATION OF THREE DEGREES OF DISPLACEMENT OF THE KIDNEY. First degree (palpable), only the lower pole is perceptible to the touch; second degree (movable), the upper pole just emerges from under the costal margin; third degree (floating), the entire kidney can be palpated. Note how the vascular pedicle suspends the kidney to a certain degree so that in the second and third stage the kidney swings over toward the mid-line of the body.

the hilum. The slipping back of the kidney with each expiration is also very characteristic (Figs. 244 and 245).

It will be remembered that in the chapter on general physical examination the fact was mentioned that tympany is usual over a movable kidney on percussion. An exception to this general rule is afforded by the floating kidneys which come directly in contact with the anterior abdominal wall. Guyon introduced a modification of this method of palpation which is of value in

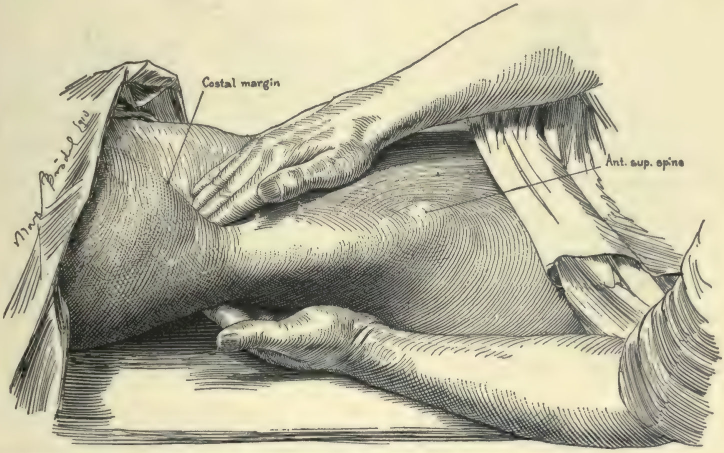


Fig. 244.—Bimanual Palpation of Right Kidney; Patient in Dorsal Posture, Left Hand Pressing Just Below the Costal Margin; Right Hand as Shown. With a deep inspiration, the upper hand is allowed to follow the abdomen upward and then presses down sharply with expiration, thus catching the kidney.

many cases, a ballottement of slight taps with the anterior hand. In the case of the kidney there is a transference of these taps to the posterior hand. This is rare with the liver or gall bladder. Nevertheless, there are not infrequent cases where both liver and kidney constitute a mass, and in such cases one naturally gets the ballottement through liver to kidney.

(2) Israel's Method.—A very useful method of examining has been popularized by Prof. Israel, of Berlin, one which sometimes succeeds when the dorsal posture fails. The patient is put in the Sims' lateral posture when examining for the right kidney, and in the right lateral posture when examining for the left. They are more easily palpated with the anterior hand in this posture than with the posterior. We employed this method for many years and think it should always be used if the dorsal position does not give the desired information.

(3) Erect Posture.—It is plain that an erect posture has certain advantages. Very exceptionally, when other methods have failed, it will give positive results. The patient puts the foot of the side to be palpated on a stool, which brings a flexion of the hip on the body; at the same time he bends slightly to the same side. This relaxes the abdominal walls, and he takes deep breaths and lets them out exactly as in other methods.

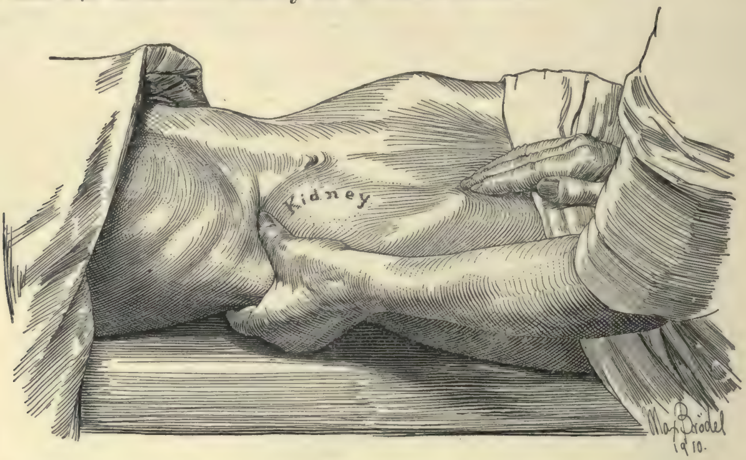


Fig. 245.—Catching and Holding the Displaced Movable Kidney so as to Prevent Its Ascending During Inspiration. This is a very convenient maneuver.

Percussion.—In palpating for the kidney bear constantly in mind the necessity for very careful examination, particularly so in thick, fat people, for a very movable kidney and one that cannot be palpated may escape notice, and before deciding that there is not a palpable kidney it is always necessary to make at least two careful examinations.

The method of injection of which we have spoken, and which we will describe later in full, will give the information when the kidney is the source of the symptoms in those cases which are not palpable, and we must bear in mind that in some of these cases the symptoms are caused by a movable kidney not detectable by palpation.

Of injection we will speak later, and now for a word on one of the earliest methods used in reference to the localization of the kidney, i. e., percussion. The idea was that with a kidney in normal position there would be dullness in the flank, and when the kidney was not present in the flank tympany would be present. This theoretical reasoning is not practically borne out by facts, and so frequent are the exceptions in both directions that we do

not employ percussion in our examination. The method consists in having the patient lie on the side and percussing the kidney region from behind and in front during deep inspiration, and then during expiration.

The X-ray in Movable Kidney.—Skiagraphic diagnosis is beginning to be more applied to movable kidney than formerly. It serves not only to exclude stone and other diseases, but will also accurately show the degree of movability if one plate be taken in the reclining and another in the upright postures. This can be shown still better if the X-ray is combined with a collargol injection of the pelvis.

Fowler, of Denver, Colorado, from his operative experience, places great value on this method. He states that those cases are always relieved which show a kinking of the ureter to the pelvic junction in the upright picture, and if this does not show in the skiagram there is no relief. While agreeing to the first part of this statement, our experience does not conform to the second. Not every movable kidney is a painful kidney because of kinking of the ureter of the pelvis alone.

Urinary Examination.—This should be most careful and systematic in the case of movable kidney. It is the negative urinary findings and the exclusion of other kidney diseases that make it important. An uncomplicated movable kidney in the intermissions between acute attacks is not associated with any abnormal change or constituents in the urine. During an acute attack of Dietl's crises there are occasionally albumin and casts, and very occasionally a few red blood cells in the urine. But it is of uncomplicated cases and not those associated with marked hydronephrosis that we here speak. The changes in the urine in association with a severe attack are exceptional; when present they are very transitory in nature, and quickly disappear. Most cases, even during the attack, will show practically normal urine, and the presence of abnormal elements should most certainly suggest some other diseases of the kidney in addition to its mobility. The possibility of albumin and casts and blood appearing during an attack is shown by the experiments of Menge, who in a series of twenty-one cases among chlorotic women and girls showed albumin was produced in fourteen cases by palpation of the kidney, and in five there was also a microscopic amount of blood. The urine in every case cleared up within twenty-four hours.

Southerland estimates that 5 per cent. of the cases of orthostatic albuminuria are due to movable kidney. Blum, in his study of movable kidney in children, out of thirty-five cases where movable kidney was found, notes eight of orthostatic albuminuria. Mosney reports an interesting one of this kind which he cured by means of a bandage. In our entire series only two showed blood in

the urine at the time of examination; ten, albumin and casts. A reconsideration of the two cases where blood was found inclines us to put them among the essential hematurias. In a group of twenty such cases we have had four of movable kidney, in addition to these two. This makes the percentage of hematurias with movable kidneys about the same as that of hematurias with kidneys that are not movable. In ten cases where albumin and casts were discovered as persistent elements of the urine we did not cause these to disappear in a single one by operation. Suspension of the kidney will, of course, sometimes relieve pain, but not with such surety as in uncomplicated cases. In the ten cases where albumin and casts were present we obtained relief of pain in five and failed in five. It has long been noted that the amount of urine during an attack of Dietl's crises is diminished, and immediately subsequent to it there is a hypersecretion. You remember we have already quoted the movable kidney as usually secreting less fluid and less solid constituents than does its fixed fellow. The presence of pus in the urine always signifies that some other disease is present than movable kidney, and the same may be said of the presence of bacteria.

Cystoscopic Examination with Catheterization of the Ureters and Injection of the Renal Pelves.—The method of pain reproduction which we use and which one of us (Kelly) described some years ago as a routine measure, is a valuable and necessary adjunct in diagnosis. It is more certain and more accurate than the influence of posture and pressure upon the kidney, which we also employ in every case. The latter have a distinct value, however, and not infrequently by simply dragging on the dislocated kidney one reproduces the pain complained of. Taking the Sims' lateral posture is particularly efficacious in reproducing kidney pain. Under the chapter on hydronephrosis we have described fully the method of catheterizing the ureters and the method of injecting the renal pelvis. It is there pointed out that by the injection both the size of the pelvis in cubic centimeters and the pain can be determined. One should always remember to use a large-sized catheter, and to test against reflux by using a colored solution; methylene blue answers very well. In sixty-five cases where we have employed this method and kept accurate notes, sixty-two gave a positive response; that is, the pain reproduced by injection was identified by the patients as exactly similar to that which they had complained of. Out of these sixty-five, seventeen have been lost sight of. Out of forty-eight cases of which accurate records were kept, forty-four were relieved and four not so. An analysis of these four shows in one case a persistent albumin and casts, in another associated pelvic inflammatory disease, in a third marked descensus of liver and stomach as well as kidneys, and in only one apparently nothing ex-

cept a movable kidney. The advantages of such a method are, therefore, quite apparent. The pain will thoroughly distinguish between the kidney and other organs; it of course does not distinguish between the kinds of kidney pain. It is of interest that cases with beginning hydronephrosis, where the pain is presumably due to a blocking of the ureter, have the pain reproduced by injecting the kidney as one would presuppose, but the pain is also reproduced when there is no evidence of a hydronephrosis. It is also reproduced in the essential nephralgia cases. Out of sixty-five examinations, nine showed a renal pelvis of more than 20 c. c. capacity. Now the average normal capacity is only about 5 c. c., the upper range of normality 12 c. c., so it is evident that in one out of seven there was beginning hydronephrosis. Out of nine such cases we lost sight of two; the other seven were cured. This method of injecting the pelvis of the kidney to the point of pain and estimating the size of the pelvis has proven of much value in clearly diagnosing and proving the disease to be due to the movable kidney, and has led to excellent results.

Under General Technique will be found details of catheterization.

Diagnosis.—From what goes before it is clear how a movable kidney is to be diagnosed and other diseases of the kidney excluded. It is mainly done by the cystoscopic and urinary examinations. Diseases of the appendix, of the stomach itself, and the gall bladder and its ducts are especially to be excluded. Differentiation of such conditions is only to be made after a most careful history taking and a thorough investigation of the condition of all abdominal organs. The commonest source of error as to the tumor is a distended gall bladder, while the pain due to a chronic appendix is the pain most frequently confused with that of a movable kidney.

TREATMENT.

Most essential of all is fixing and holding it in place. This can be done by operation or by mechanical and hygienic methods. The question which presents itself to the physician is to tell which movable kidneys to treat and what kind of treatment to use in individual cases. From what has already been said in regard to the occurrence of symptoms and the pathological significance of movable kidney, it is manifest that the vast majority of cases should not be treated at all; here, of course, we refer to cases which give no symptoms. A few cases of early hydronephrosis would possibly be discovered by catheterizing the ureter and measuring the pelvis in every case of movable kidney, but such a finding would be so rare that the examination would be unjustifiable. Cases of this kind practically always begin giving symptoms. If, therefore,

a physician finds during an abdominal examination that the kidney is movable, and is sure that it has never given any symptoms, and the patient does not know about it, he should take particular care to leave her in happy ignorance of the condition.

The prophylactic measures to be taken to prevent movable kidney are suggested by what has been said about the etiology of the condition. People who have that peculiar body form so frequently found with movable kidneys should from childhood be given exercises to strengthen the abdominal wall, should not wear tight bands about the lower chest, should be kept in a condition of fair nourishment, and, if possible, should be kept from violent straining exertions. At labor particular care should be taken. We do not consider that belts or bandages should be worn as a prophylactic measure.

Non-operative Treatment.—Various forms have been devised to obviate an operation, notably bandages and belts, rest in bed, and fattening, massage, and psychotherapeutic measures. Let us take them separately.

Bandages, Supports, and Belts.—It is beyond question and has long been known that a well-fitting bandage can give complete relief from all symptoms occasioned by movable kidney, but the observation of its first user, Rayer, that relief was afforded only in some cases is still maintained. Very many of our own cases had used bandages before operation, most of them receiving some benefit, and occasionally complete relief had followed. Here is a case:

Mrs. W. M. C., San. No. 1,922, age 28, April 4, 1905. The patient gave an excellent family history, had had no previous diseases except that menstruation had always been irregular and painful. The present illness consisted of a dragging pain in the right side, present for some months, and increasing in severity during the menstrual periods. There were no acute attacks of pain; no digestive or nervous symptoms, nor was the right kidney movable to the first degree. Injection of its pelvis with 1 c. c. of fluid reproduced the pain. Urine was normal, also temperature and pulse. A well-fitting bandage relieved the symptoms, and she wrote two years later that she had had complete and permanent relief but is still wearing the bandage.

In common with other forms of treatment, a great diversity of views are held as to the value of a bandage. Morris considers it practically of no value; Glénard holds it very effective; Edebohls reports very little relief; Hegar in twenty-two cases secured relief in only two; while C. D. Aaron gives 95 per cent. of cures out of four hundred and forty-two cases. Of course the kind of case and the skill in fitting bandages must be taken into account. Let every man treating movable kidneys learn thorough methods of fitting bandages, and not leave it to the bandage-maker. In every case the bandage should be

seen on and corrected to fit properly. As to length of time of wearing, this cannot be definitely stated. In cases where the symptoms have long been present and are marked it must probably be worn permanently; where the symptoms are not severe and only present a short while, a few months may be long enough.

Kind of Support.—Almost as many kinds of bandages have been devised for movable kidney as operations to suspend it. The principles involved are two; the first aims at a firm support to the entire abdominal wall, and to bring a pressure from below upward over the entire abdomen; the second, to produce a pressure immediately below the kidney which will prevent its coming down. A well-fitting bandage of any kind effects the first, and the second is effected by a belt around the abdomen, and by a truss with a large pad, resembling those worn for inguinal hernia; various forms of spring truss have been devised for this purpose. It is possible to combine the two by putting a pad on the inside of the bandage, so that it comes just below the kidney. Schmitz has introduced and claims excellent results from the use of wide bands of adhesive plaster. These, ten centimeters wide and forty centimeters long, are passed around the body. Our own form, which is cut and accurately fitted to each patient, is composed of durable material, takes a firm grip of the pelvis, extends up to and includes the twelfth rib, and is held down by rubber bands passing underneath the body. In most cases we have not noted any benefit from special pads, but occasionally put them in. We do not think the use of trusses justifiable, for serious results might occur from the imprisonment of the kidney underneath one. If this complication occurred, the kidney would be injured rather than bettered. The same principle applies here that applies to irreducible hernias. The bandage should be worn during the day and taken off at night. But under Operative Treatment will be found further indications and suggestions.

Rest in Bed and Fattening.—This is a treatment manifestly not applicable to patients who are already fat and whose sole symptom is pain in the kidney. But that much can be done with it in patients with marked gastric disturbance and emaciation is beyond question. It is a valuable adjunct to both the bandage and the operative treatment, and is a method much employed by stomach specialists; in fact, Einhorn has recently reported seven cures. It takes time, however, and is expensive, and we do not hold it very effective in that class of movable kidneys which give definite local symptoms. Morris considers it perfectly useless. Be guarded, therefore, in promises to patients who are taking such a treatment.

Massage.—We have had no personal experience with massage and would

not recommend it, since direct massage of the kidney would certainly result in injuries to the kidney, as Menge has shown. In a very interesting way R. Rumpf has reported the results of deep massage underneath the movable kidney, and believes marked benefit to be had through this treatment. He assumes that adhesions are formed beneath the kidney which help support it, and Eisenberg has also secured favorable results.

Operative Treatment.—As at present understood, this is confined to suspension or fixation of the kidney, but the first operation ever performed for movable kidney was nephrectomy, carried out by Martin in 1878 in two cases; then, following his lead, a number of surgeons removed kidneys because they were movable. We mention nephrectomy here merely to condemn it, for, as seen from what has been said, movable kidney is not a disease involving destruction of the kidney, or threatening life, and removal of the kidney means removing just so much vital renal tissue from the body, while even at the present time the mortalities from nephrectomy would be greater than those from simple suspension. We have never found such an operation necessary. In collecting, mostly from the literature between 1880 and 1890, 42 cases, Wagner finds 25 per cent. of the patients died, a fact doubtless explained by the faulty technique of that period. Nephrectomy for movable kidney is now rare, and one of the last we have been able to find is that of F. Weidner, who reports two cases where relief of pain was not obtained by suspension of the kidney, and was gained by a nephrectomy.

Suspension of the Kidney.—The first step in this direction was taken by E. Hahn, of Berlin, who in 1881, attempted in two cases to fix the kidney by sewing the capsule of Gerota and the fatty capsule of the kidney into a lumbar incision. His lead was followed by a number of operators, but it was some time before the inefficacy of the method became evident; the reason being, of course, manifest when it is remembered that the kidney moves readily in its fatty capsule, and that the capsule of Gerota is open inferiorly. Other methods then developed, and the present time numbers many efficient ones. How to decide among them? Well, the rules which apply to surgery everywhere apply here. If several operations give the same results, that is to be employed which is most easily done and subjects the patient and the part operated upon to the least injury. Study a little the kinds of operations which have been devised to learn what factors play a part in this problem.

Before giving our method we will take up some of the points debated in regard to fixation of the kidney. How much of an operation is necessary to securely and permanently fasten the kidney? At what level should it be attached? What is the result of passing sutures through its substance? Is

there a difference between sutures which are only placed temporarily and those which remain permanently? What is the result of decapsulation?

Glance a moment at the attempts at suspension. Those in which the kidney was suspended by its fatty capsule alone were all failures. The next step to secure a fixation was made by E. Bassini, in 1882. He passed sutures through the fibrous capsule of the kidney as well as the fatty capsule, and the capsule of Gerota, a method which likewise yielded insufficient results. Newman, in June, 1884, reported a method where he passed silk sutures through the parenchyma of the kidney, and Tuffier, 1890, was the first to particularly emphasize the necessity of removing the fatty capsule, and so bringing the fibrous capsule directly in contact with the muscle, thus securing firm adhesions; Wolff, Watson, and Morris about the same time urged the use of chemicals of an irritative nature in addition to the sutures, with the idea of securing firmer adhesions. Up to 1890, when Tuffier recommended closing the incision, all such cases were drained, with this same idea of further strengthening the adhesions. An interesting group of methods are those which aim at making a pocket in the abdominal wall in which to place the kidney, notably those of Jaboulay, Senn, and Pean. All are efficacious as far as fixation is concerned, but require a great deal of manipulation of the kidney. The earliest operation of this kind was devised by Hochenegg in 1891. With the idea of escaping the necessity of putting sutures through the kidney, various authors have advocated methods of supporting it in a kind of hammock. Rovsing and Bazy have devised methods of sewing the peritoneum from the anterior surface of the kidney into the lumbar wound, and Witzel has made a regular network of sutures underneath the kidney, whereas Deaver and others passed gauze drains below the lower pole of the kidney and scarified its posterior surface. Further developments of those methods which aim at fixing the kidney by means of its fibrous capsule alone have been pushed to a high degree of perfection. G. M. Edebohls splits the fibrous capsule along the convex border of the kidney, rolls it up on both the surfaces, sutures the rolled-up fibrous capsule on the anterior face of the kidney to the anterior lip of the incision, and that on the posterior face to the posterior lip. The suture material which he employs is forty-day catgut. Buedinger, J. F. Baldwin, and many others have used methods by which the fibrous capsule is stripped off the posterior surface of the kidney, and the stripped off capsule sewn to the muscles of the back. Vulliet and Sotocasa used tendons of the erector-spinæ and quadratus lumborum muscles in place of sutures with which to suspend the kidney, and an even more striking method of this kind is that employed by Mariane, who shells the twelfth rib out of its periosteum and passes this periosteum through the kidney. Work on dogs

shows that using the periosteum does not regenerate bone. Mariane reports ten cases; in each he kept his patient in bed ten days and in all had perfect results.

The methods so far described are all done through lumbar incisions. This has supplanted all others except in unusual cases, such as the one described, where, after exploring the gall bladder, it was found convenient to fix the kidney through the same incision. Rosenberger, in 1888, was one of the first to devise an abdominal method. He sutured the peritoneum firmly to the kidney, and made the kidney partly an intra-abdominal organ, a method not very efficacious, and one which gradually passed out of use.

To fix the kidney well it is essential to place sutures of such a kind into the kidney that it is temporarily held firmly against the muscles of the back until fibrous union has taken place, this being unquestionably facilitated by scarification of the fibrous capsule, or even its partial removal. The fatty capsule must be carefully removed wherever it could come between the muscles and the kidney. Many of the methods described would undoubtedly fix the kidney but are operations of considerable magnitude, requiring much manipulation of the kidney and taking considerable time. The level for fixation has also been a fruitful point of discussion, some believing it necessary that the kidney should be suspended high up in the loin, and others being equally sure that, no matter where fixed, the results will be good. Riedel was the first to urge the high fixation. He passed his sutures through the middle and lower thirds of the kidney and pushed a piece of iodoform gauze up between the upper pole and the diaphragm, thus producing adhesions between the diaphragm and the very top of the kidney. One of the earliest operators to suspend the kidney around the twelfth rib was Guyon, who reported this method in 1889.

It is evident from what we have said concerning pain due to kidney mobility and concerning the shallowness of the renal niches as a cause of mobility, that each case must be decided on its own merits. In patients with a well-shaped body, and where the kidney can readily be drawn up, excellent results are secured by suspending the kidney to the twelfth rib. On the other hand, in those where there is very little space above, such fixation does not seem to be called for; in fact is contra-indicated. We decide this point by the ease with which the kidney can be pushed up. If it readily resumes its place, it should be put up high; if not, it can be sutured lower than its normal position. Let the operator make careful observation as to whether the ureter is free and in its proper relation to the pelvis of the kidney; whether there is any twisting of the kidney or its vascular pedicle, or any tension on the parts. It should be sewn so that all of these relations are normal. These are simple rules to

observe, but they insure excellent functional results by either high or low fixation. Other things being equal, however, it is better to fix high, as the kidney is then removed further from likelihood of injury, due to pressure or accident.

As already pointed out, certain methods of operation have been devised, intended to avoid passing sutures through the kidney substance, and other operations have been employed in which the sutures are absorbable, as those of catgut, or removable, all with the idea that permanent sutures are more harmful than temporary sutures. Guyon was one of the first to use catgut sutures in kidney suspension, a plan followed by many operators. Jonnesco, in 1897, appeared as an advocate of removable sutures. He passed the sutures through the kidney substance, and brought them out through the skin, removing them at the end of ten days.

The necessity for such operations must be determined by results. What are the differences between temporary and permanent sutures? In our experience we have never observed any injurious effect clinically to the kidney from leaving fine black silk sutures in place. Immediately after operation for a few days there will be a little albumin, a few casts, and a few red blood cells, which, however, quickly clear up and leave the urine normal. There is little ground for the fear entertained in some quarters that these sutures make a kidney more susceptible to infection, and the subsequent history of our own cases has proved this. The result of passing a suture through the kidney is that there is a destruction of the epithelium lining the tubules, and of the glomeruli immediately in contact with the suture, but this is of small amount and leads to very little destruction of active kidney tissue. The inflammatory reaction, as E. R. Elmgren has shown, is slightly less after the use of catgut than after silver wire or silk. Nearly all observers have met with similar findings, and Max Wolff, in his interesting monograph, "Die Nieren Resektion und ihre Folgen," deals fully with this. If the fatty capsule is stripped off, there is firm adhesion produced in most cases between the kidney and the muscles of the abdominal wall, and here we might say that sutures which have remained in ten days, as Jonnesco advises, produce about as much fibrous change as those which stay in permanently.

Many experiments have been made as to the effects of decapsulation since Edebohls published his treatment of Bright's disease. The results are practically uniform, showing that a new capsule is formed which is attached both to the kidney and the surrounding structures, and forms a strong adhesion to the abdominal wall. The questions of chronic nephritis and the amount of blood supply afforded by this new capsule to the kidney will be taken up under their special headings.

Here it is merely necessary to note that very little destruction, or none of the cortical layer, is due to such decapsulation, as well as the absence of injury to the kidney.

Technique of Suspension.—Our method (the Kelly method) has been evolving during the past sixteen years, but I (Kelly) originally began by passing straight sutures through the kidney, including the parenchyma, and in some cases used sutures that were removed subsequent to operation. The plan at present employed is simple in execution, affords a firm support to the kidney, leads to the formation of strong adhesions between it and the abdominal wall, and affords excellent functional results. The steps of this operation are excellently shown in Figures 246, 247, 248 and 249.

Position of Patient.—The patient is placed on the table, lying on the abdomen, the face turned toward the side to be operated upon. Resting between the upper part of the abdomen and the table is a partially inflated Edebohls bag. The patient is placed on this bag in such a way that the side to be operated upon is uppermost, and there is a distention of the loin between the twelfth rib and the crest of the ilium (Fig. 246).

The Skin Incision.—Having thoroughly cleansed the skin and the field of operation, make an incision beginning above over the superior lumbar triangle, and carried outward and downward at an angle of about forty-five degrees. Six centimeters is the average necessary length of such an incision; in many cases it is shorter, while in others it is considerably longer. The superior lumbar triangle can be located by pressing with the fingers in the angle between the twelfth rib and the spinal column. At this point the musculature is the thinnest and one gets the sensation of a soft spot. This incision extends through the skin and subcutaneous fat and brings the operator down to the superior lumbar triangle, as shown in Figure 246. This triangle, corresponding in a way to Petit's triangle below, lies between the latissimus dorsi and external oblique muscles. In many cases this triangle comes plainly into view; in others, where the latissimus dorsi is very well developed and very wide, there is an overlapping of the external oblique muscle, and in such cases it is necessary to cut through the fibers of the latissimus dorsi, which may be done either transversely across the fibers of the muscle or by splitting of the fibers. In either case one retracts the incision so that the lumbar fascia comes into view, as shown in Figure 246. The fascia here has a white, shining appearance.

Puncture of Fascia.—With the muscles retracted on each side by the assistant, a blunt clamp is pushed through this fascia. Immediately is seen the yellow subperitoneal fat, as excellently shown in Figure 246. The

opening in this fascia after puncturing can be conveniently carried out by blunt stretching with the fingers (Fig. 246). Considerable strength can be utilized here and very little hemorrhage is occasioned. The external edge of the quadratus lumborum muscle lies on the inner edge of this incision. By

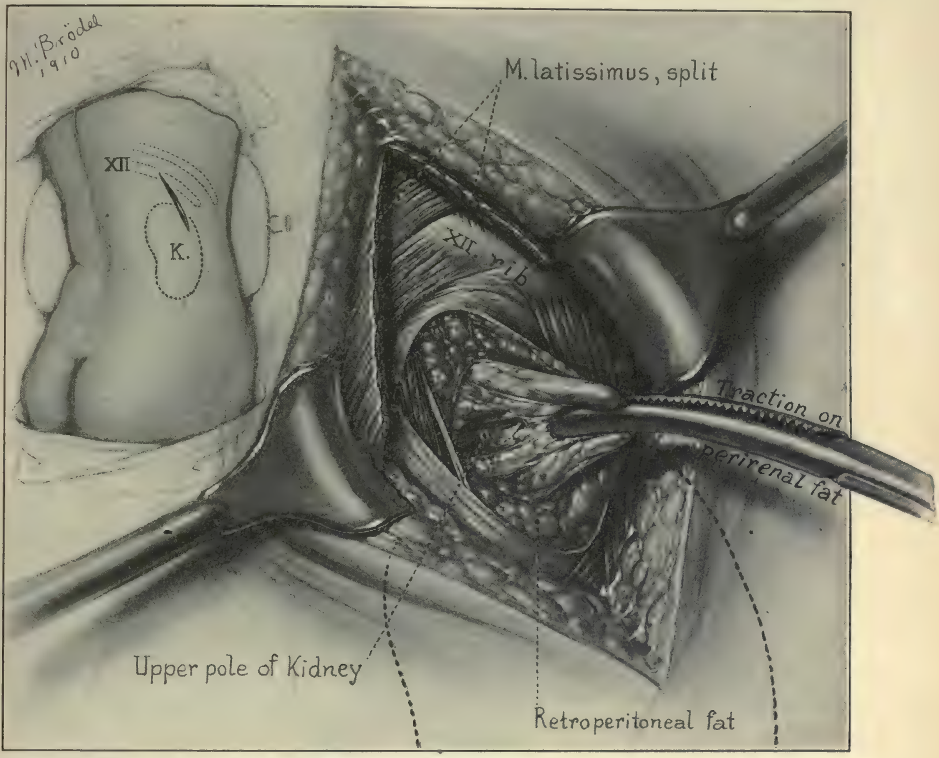


Fig. 246.—Typical Incision for Suspension of Kidney. In this case a wide M. latissimus dorsi requires its being cut across transversely for a little distance. Superior lumbar triangle between M. quadratus and lateral muscles already opened. Perirenal fat grasped with traction forceps. Kidney just visible.

pulling up the fat and working down toward the kidney, the thin fibrous capsule of Gerota is brought into view (Fig. 246). This can be torn open with the fingers, when the pale, soft, fluent, lemon-colored fat immediately surrounding the kidney comes into view, easily recognizable by its color and consistency, in marked contrast to the subperitoneal fat.

D r a g g i n g o f K i d n e y i n t o V i e w.—In many cases the position of the patient on the bag has pushed the kidney back under the ribs, and in

order to bring it into view a number of clamps can conveniently be applied to the fatty capsule (Fig. 247). It is necessary in doing this to have at least half a dozen, as traction on one only tears through the capsule. Gradually

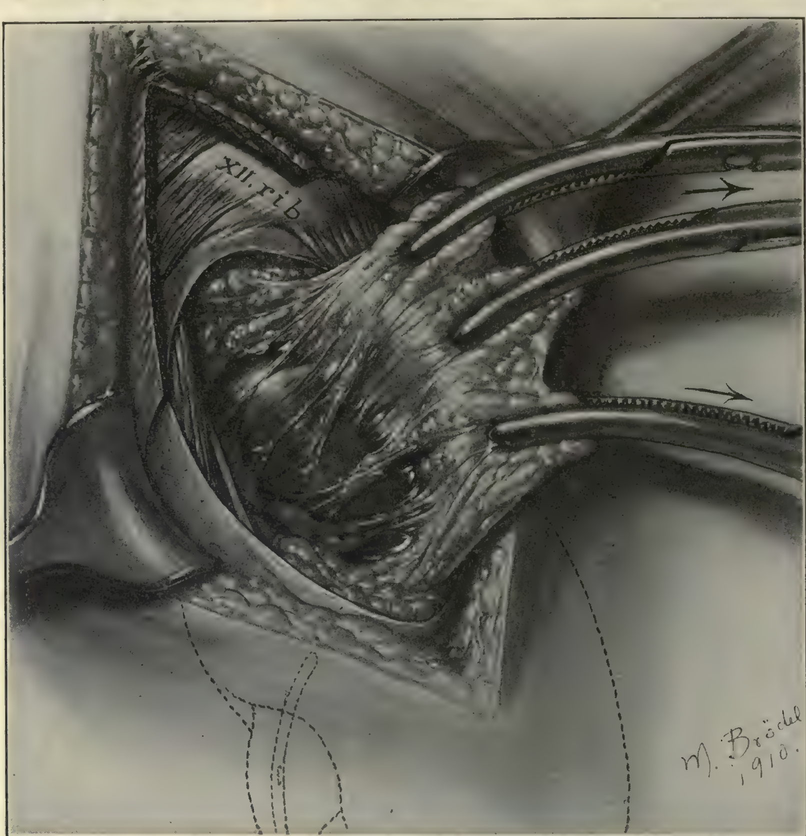


FIG. 247.—EXPOSURE OF KIDNEY BY TRACTION ON PERIRENAL FAT. Several forceps must be applied, one after another, from above downward. Handled in this way, the least possible trauma is done the kidney. Outline of kidney and renal catheter are seen below. The introduction of a catheter before operation greatly facilitates exposure of uretero-pelvic junction.

dragging down the kidney by means of these clamps, it is brought into view, and can be seen moving up and down in the incision. The fatty capsule is then stripped off the entire posterior surface of the kidney and upper pole, the pelvis of the kidney is palpated, its ureter located, the pedicle felt, and the kidney itself inspected. It is not necessary to deliver the kidney outside the

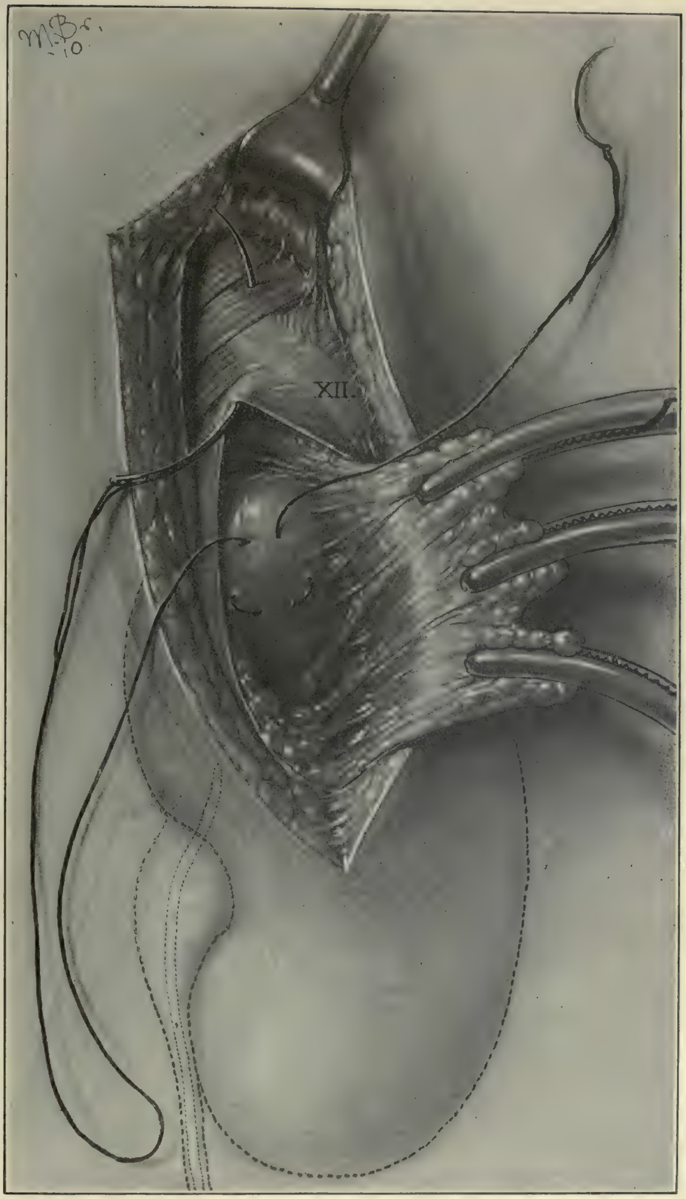


FIG. 248.—SUSPENSION OF THE KIDNEY: INTRODUCTION OF FIRST SUTURE. Note triangular suture in kidney on its posterior surface. This suture is placed with a delicate needle, the two free ends then carried with a coarse needle, as shown in figure, above the twelfth rib. This affords a high position to the suspended kidney.

incision to do this, but all can be thoroughly explored with the kidney lying in the abdomen.

Placing of Sutures.—To use those of fine, strong, white silk and place them in the kidney by means of a small curved French needle is our

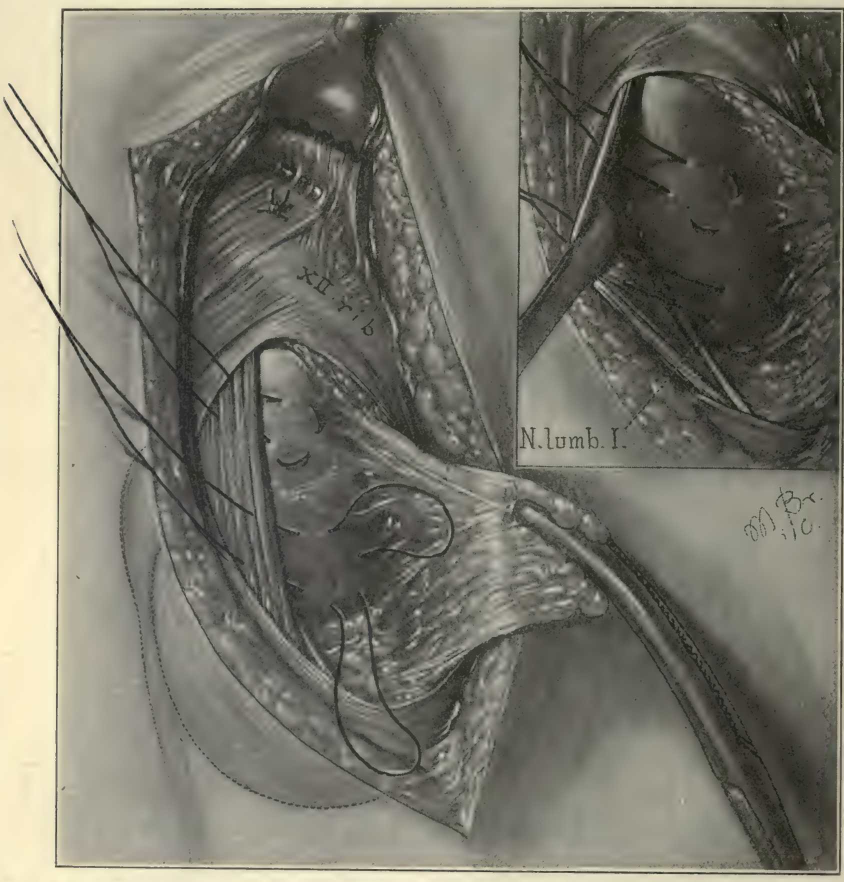


FIG. 249.—SUSPENSION OF THE KIDNEY: UPPER SUTURE TIED. Two additional triangular sutures placed in kidney, as shown, fastening it to M. quadratus lumborum. Right-hand figure shows first lumbar nerve which must not be caught in sutures.

plan. If the kidney readily goes back above the twelfth rib, as we have already considered under fixation of kidney, we begin by dissecting underneath the skin and fat at the upper angle of the incision until the upper border of the twelfth rib is reached. The suture to be used is put in a large curved needle

and passed above the twelfth rib through the wall (Fig. 248). The inner end of the suture is then threaded on to a small French needle and passed through the kidney at the junction of its upper and middle thirds and near the outer border. The stitch employed is one devised by M. Broedel, a triangular one, as shown in Figure 249. The first side of the triangle is taken with the first stitch, which is then passed through the base of the triangle and the other side. The end of the stitch which is passed through the kidney is then threaded on to the large needle, and this passed over the twelfth rib again. A similar stitch is put through the lower pole, and one also placed midway between the upper stitch and the lower. The free ends of these two stitches are sutured through the outer border of the quadratus lumborum muscle. Special care must be taken to insure against the involvement of the nerve which courses along the outer border of this muscle. This nerve is readily found and should be pushed downward toward the middle line. When all the stitches are applied they are drawn up and tied snugly, but not with great pressure. The tying absolutely controls the little hemorrhage occasioned by their passage through the parenchyma of the kidney. Their depth in the kidney is never greater than 1 cm., and the danger of striking a calyx is obviated (Figs. 248 and 249).

Treatment of Fatty Capsule.—When this is very abundant, we excise part, ligating the cut vessels with catgut sutures. The part left behind, or the whole, in cases where we do not feel the need of removing it, is sewn into the incision, being brought up and attached to the quadratus lumborum muscle.

The final step of the operation is closing the incision, and this is done in layers with catgut. If the latissimus is cut, it is sewn together, and in all cases it is brought over the external oblique so as to close in the superior lumbar triangle. We usually employ thin catgut sutures in the fat, and close the skin with a subcutaneous catgut suture.

Anatomical Results of Kidney Suspension.—The old methods certainly did not give firm and permanent suspension, and we think now that if our method, with three silk sutures, and a scarification of the capsule, is carried out an excellent result will be obtained. Take great care that the broad surface of the kidney unites, and be particularly careful not to suspend the lower pole and leave the upper pole free. H. W. M. Gray has reported a case in which serious trouble has resulted from this, and in our own series there have been several early cases in which suspensions of this kind were done, and symptoms observed after the operation. In one interesting case we operated a second time and found the kidney well fixed at its lower pole, but with the upper pole markedly movable. We give the history:

Miss M. F., Gyn. No. 7,731, age 33, April 9, 1900. Symptoms, attacks of pain in the right side, induced by physical exertion, lasting for twenty-four hours at a time. Attacks had been present for three years, and gradually grew worse. Physical examination showed nothing except a very movable right kidney, and injection of this reproduced the pain. The kidney was suspended to the quadratus lumborum muscle by three silk sutures. Patient returned a year later, stating that she was fairly comfortable with a bandage and had had no attacks, but there was a constant dragging in right side, made much worse whenever she exercised severely, which she was more or less compelled to do as a teacher of physical culture. A second operation undertaken at this time showed pelvis of kidney normal, its lower pole firmly fixed to the abdominal wall, but upper pole was very movable. A suture was placed in high up which held the kidney firmly in place, and a year later this patient reported herself perfectly relieved of symptoms.

Curiously enough, the eleven cases where there has been a return of pain and, to the patient's belief, some recurrence of mobility, are all prior to 1902; one of the patients was the first one operated upon at the Johns Hopkins Hospital for suspension of the kidney, in October, 1891. In this case silkworm gut sutures were used and removed subsequent to operation. We have reoperated on several cases where a return of mobility was suspected, and found them well fixed. We quote the only exception:

Miss P. S., Gyn. No. 9,762, age 36, July 2, 1902. Marked attacks of pain in right side of abdomen for three years, was strong and healthy-looking, showed no disease except a right movable kidney. This was suspended to the quadratus lumborum muscle by two silk sutures, introduced in the triangular manner described under operative section. This patient was relieved of her symptoms for eight months, when she suddenly had a fall, and the kidney became movable again. Eleven months after her first operation, June 9, 1903, a second was done. It was found that sutures had pulled out and kidney had regained its mobility. It was suspended this time with three silk sutures, and the patient had no return of the trouble.

It is of some interest that the recurrent cases have been, without exception, those in which only two sutures were used, and in which the suspension was entirely to the quadratus lumborum muscle low down. All the cases, too, except one, occurred in the period between 1899 and 1902. Since that time there has not been one. Treatment of the fatty capsule seemed to be of no importance. In about half of them it was sewn into the incision, and in the other half cut away. Carried out, however, as described, the operation will give a perfect anatomical fixation.

It is needless to say that a badly suspended kidney can do much harm, as shown by a case at the Cambridge Hospital. In this instance there was a movable right kidney which had been faultily suspended by an experienced surgeon and which had given the patient a good deal of pain. This kidney was freed and resuspended, since which time the patient has been quite comfortable.

Post-operative Complications.—We have had no serious ones. The patients usually make a rapid and easy convalescence, though, as a rule, there is considerable pain immediately after the operation, and for several days it is necessary to keep the patient perfectly quiet on the back; not until two weeks after should he be allowed to turn on the opposite side to that of the kidney suspended. We have had four cases of right-sided phlebitis following suspension of right kidney, but in every case there was a suspension of the uterus also. In three of the very nervous patients there were pronounced mental symptoms approaching acute mania after the operation, but all promptly recovered. Two of these have been lost sight of as to permanent relief, and in only one case are we able to report that there has been not only a relief of the post-operative mental condition, but also a relief of all symptoms. In a number of our early cases there was infection of the incision, but this has become a great rarity, and there has never been a serious case of it.

Other operations might give rise, of course, to other complications. Morris, v. 1, p. 134, reports a case where he injured the pelvis of kidney during a suspension, and Gardner reports three cases from Albarran's clinic where suspension of kidney was followed by a lumbo-renal fistula requiring nephrectomy. He attributes these fistulæ to a piercing of the calyx by the suture, and advises that, to avoid this, these be placed not too deeply. Frank reports a case where intermittent hydronephrosis followed suspension; but this, of course, must have been due to improper fixation.

Mortality.—This is very low. Morris in ninety-eight cases had only one death, from cardiac thrombosis. Albarran, who collected three hundred and seventy-four cases from the literature, reports four. Edebohls, in eight hundred and forty-six cases from the literature, notes ten. Tuffier, in seventy-two personal cases, that he reported at the Congress of Moscow in 1897, had two deaths. Goelet, in one hundred and ninety-seven personal cases, has not had one death. In our own two hundred and forty-five cases there has been one death, due to general peritonitis, the cause of which was never ascertained, as there was no local involvement of the incision or the region round about, and the patient did not have the peritoneal cavity opened during operation.

Functional Results.—A fair idea of the functional results of kidney

suspension has now been gathered. For the sake of simplification we take the cases in groups.

Cases Where Right Kidney Alone Is Movable.—To this group belong one hundred and fifteen cases. Of these eighty-five have been cured, twenty-three lost sight of, and seven reported as failures. In going over these seven cases, only one is typical and uncomplicated, and here there was no injection of kidney. The remaining six had other complications which could easily account for non-recovery. Three of them were associated with pelvic inflammatory trouble; in one casts and albumin were in the urine, showing it a case of nephralgia; and in one a chronic appendix and ovarian cyst were removed, the injection previous to operation showing the pain not a renal one. This operation was done at a time when we were not so confident as to the results of this method. In the last there was 10 c. c. of the ureter dilated, showing some other trouble to be present besides movable kidney.

Taking this group of cases from the standpoint of stomach symptoms alone, sixty-eight were found to have them. Out of these, thirteen have been lost sight of, leaving fifty-five. Forty-six have been relieved, and of nine, where the stomach complaint was not relieved, only three had uncomplicated movable kidney. The others had either pelvic inflammatory disease or appendicitis, and operations were done on the pelvic organs and on the appendix at the same time as on the kidney.

Most interesting is the fact that, out of this same group, thirty-three complained of nervousness, and, out of the thirty-three, twenty-one reported themselves very much improved, eleven were lost sight of, and one was not relieved.

The results, as far as suspension of left kidney alone are concerned, are very similar as regards pain and nervousness. As already pointed out under symptomatology, it was quite otherwise with the gastric symptoms. These do not occur commonly with movable left kidney alone, and, if they do occur, arise from some other cause than the kidney. Out of fifteen cases where we have suspended and the left kidney alone was movable, seven were cured, six lost sight of, and two were failures.

Results Where Both Kidneys Are Movable.—Operative results when both kidneys are movable are best classified into the results in the cases where the two kidneys are movable and there is no general enteroptosis, and into the cases where there is general enteroptosis with both kidneys movable. Out of the forty-four cases, twenty-three showed general enteroptosis, and twenty-one not. We operated forty-one times, and of twenty-one cases where both kidneys were suspended, twelve have been cured, three lost sight of, and

six have been failures. In thirteen of these the right kidney alone was suspended. In this list five were cured, five failed, and three have been lost sight of. In eight, where the left kidney alone was suspended, four were cured, two lost sight of, one was a failure, and one was relieved of pain, but not of the gastric symptoms. In twelve cases with general enteroptosis and both kidneys movable where both suspended, there was complete relief in seven, and in five failure to get relief. In ten cases where both kidneys were suspended and there was no general enteroptosis, there were six cured, one was a failure, and three were lost sight of.

In eight cases with general enteroptosis and double movable kidney, where the right kidney alone was suspended, five were relieved, two lost sight of, and one was unrelieved. In five cases where both kidneys were movable and no general enteroptosis was present, the right alone suspended, three were cured and two lost sight of. There were three cases where both kidneys were movable and there was general enteroptosis; in two of the three we suspended the left kidney only, but both have been lost sight of. In six cases where both kidneys were movable without general enteroptosis, we suspended the left kidney only; five of these were relieved and one was a failure. In the failure there were casts and albumin in the urine, and in one of the five successful cases marked gastric symptoms not relieved by operation.

With Double Movable Kidney and General Enteroptosis.—Out of twenty-three cases, fifteen showed marked gastric symptoms. Out of these, six have been cured by operation, five are unimproved, and four lost sight of.

Post-operative Treatment.—After suspending the kidney, the patient should be kept quietly in bed on the back for at least three or four days, at the end of which time he can be turned on the side where the kidney was suspended. In cases of double kidney suspension he should stay on his back at least ten days. There is usually a good deal of pain complained of for the first two or three days after operation.

We prefer in these cases an anesthetic of gas and oxygen, because there is very little post-operative nausea and vomiting.

Coughs should be controlled by sedatives, and the bowels moved in such a way that there is very little straining.

The patient can be up about the seventeenth day, but should wear a bandage. It is not absolutely necessary to wear one after getting about, but we think for the first few months after the operation it is wise to do so. No heavy lifting or exercise, or anything that would be likely to dislocate the kidney, should be done. Except in the cases of marked general enteroptosis,

the bandage should be removed after two months, and even in some of these it is well to do so.

In quite a few cases there will be slight pain in the side for several months after operation, and the patients must be made to understand this. In some cases there is complete relief at once, but six months must be taken as the period when complete relief is to be expected.

Summary.—Looking now at the results of our experience, it is evident that with increasing accuracy of diagnosis and thoroughness in operating, the functional as well as the anatomical results will steadily improve. In those cases where we have thoroughly established the diagnosis by catheterization of the ureters and injection, almost every case has been relieved of pain. The statistics are given under the results of injection. The best results are to be expected in those cases where there is an uncomplicated movable kidney. It is most difficult to show that gastric symptoms are due to movable kidney, but where other sources are properly excluded, the relief is almost as frequent as in the case of pain. In gastric cases, however, it must be remembered that the right kidney is at fault, and operative work on the left kidney will not give relief. The nervous symptoms in about 50 per cent. are dependent upon the movable kidney and relieved by its fixation. The operation itself is not dangerous, and technically not difficult.

Cases in which both kidneys are movable are to be considered in exactly the same light as those in which only one kidney is movable.

If both kidneys are giving symptoms, that is, if pain is present in both sides, both kidneys should be suspended.

If the pain is only in the left side, but marked gastric symptoms are present, both kidneys should be suspended.

In the presence of local symptoms general enteroptosis is no contra-indication to operation. Cases with general enteroptosis should be treated along the line of exactly the same indications. We have repeatedly relieved patients where there has been descensus of the stomach with marked gastric symptoms by fixation of the kidneys.

Those cases where retroflexed uterus is present and giving symptoms, or where there are symptoms pointing to the appendix in addition to the kidney, should be treated at the same operation. The results here also are excellent.

We have deferred to this point a consideration of the indications for operation as against those for bandage treatment. As pointed out under consideration of the bandage, cures, in the sense of permanent relief of symptoms after the removal of the bandage, are principally met with in those cases where the duration of the symptoms has been short, and especially in those cases where

there have been no violent, acute attacks of pain. Better results are obtained with a bandage, therefore, where the pain is slight, being more of a dragging sensation, and has been present but a short time, than in those cases with marked Dietl's crises. The bandage is capable of relieving both gastric and nervous symptoms, as well as those arising from the kidney itself. Where the symptoms have been present but a short while, therefore, an attempt should be made to relieve by a properly fitting bandage, and, if the bandage does not relieve, speedy operation should be advised at once. If the bandage gives relief, but after months of trial the patient is still unable to get about without it, operation should also be advised. In such cases, however, the choice between bandage and operation should be left to the patient. Just as many people wear trusses with comparative comfort and others dislike them greatly, so certain patients will wear bandages and others tolerate them with difficulty. This advice applies urgently to those cases where only one kidney is movable.

In patients with general enteroptosis and symptoms from one kidney, perfect relief is frequently obtained by suspending the kidney, but in many of the cases of enteroptosis a bandage will have to be worn, even after the kidney is fixed. Therefore, in cases where general enteroptosis is present, and where the bandage gives complete relief, the advice should be to use the bandage alone, unless it is extremely irksome to wear it.

In all cases where there is beginning dilatation of the renal pelvis we should advise kidney suspension, and also in all cases where there are attacks of renal colic, whether there be a general enteroptosis or not.

CHAPTER XVII.

HYDRONEPHROSIS.

Hydronephrosis is the term employed to designate retentions in the distended pelvis and calices of a kidney due to some impediment to the outflow of urine. Uronephrosis is frequently used as a synonym and is perhaps a more expressive term. The urine may be aseptic, when the condition is called simple hydronephrosis, or there may be infection. Clinically it has become customary to speak of an infected hydronephrosis when referring to a mild infection in a hydronephrotic sac, but when infection is marked the term pyonephrosis is better.

For hydronephrosis to exist there must be not only retention of urine, but also a distention of the pelvis and calices. When it is borne in mind that the average human kidney pelvis has a capacity of 7.5 c. c., but that the normal varies from 1 to 20 c. c., it becomes evident that it is not always a simple matter to determine when there is distention. An idea of the actual appearance of pelves of different capacities can readily be formed from Figure 250. Note that the increased capacity may be due to dilatation of the pelvis alone, of the calices alone, or of both together. Note also that when the pelvis is entirely intrarenal the calices tend to be smaller and narrower. In Figure 251 is seen an excellent example of a distended pelvis of large capacity.

Hydronephrosis is commoner on the right side than on the left, and seems to be more frequent in women than in men. It is referable to no special period of life, and is found from infancy to old age.

ETIOLOGY.

A great number of conditions may lead to hydronephrosis, yet all have one feature in common, that of obstructing the outflow of urine from the kidney. Any obstruction whatever of the ureter or of the urethra will in the end be followed by hydronephrosis. The obstructing cause may be within the urinary tract or on the outside of it. It may depend upon abnormality of development, it may be a result of disease, or, as in many cases, it may be due to acquired abnormal positions or movements of the kidney.

FIG. 250.—CASTS OF THE HUMAN RENAL PELVIS SHOWING ACTUAL SIZE AND CAPACITY.

FIG. 251.—SAME AS LAST FIGURE IN CASES OF MORE MARKED DISTENTION, CARRIED UP TO 160 c.c. They may be far larger.

Among the developmental or congenital causes have been noted strictures of the vesical end of the ureter, a condition particularly common where the ureters empty abnormally, as into the urethra or vagina.

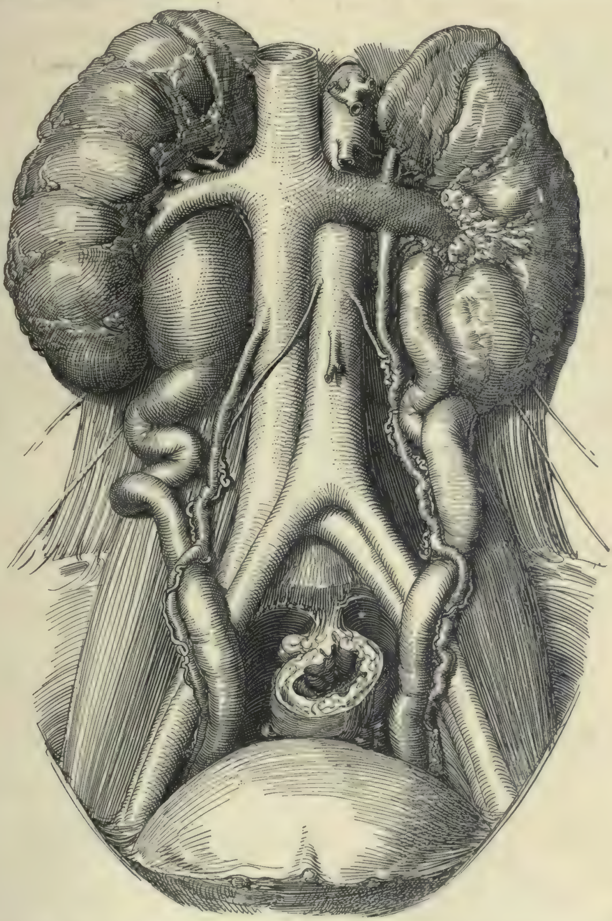


FIG. 252.—DOUBLE HYDRO-URETER AND MODERATE HYDRONEPHROSIS ON RIGHT SIDE DUE TO OBSTRUCTION OF LOWER ENDS OF URETER. Note the cork-screw twisting of ureters typical of this condition. (Autopsy observation, Mr. J. W., Feb. 19, 1902.)

Such kidneys are almost without exception accompanied by distended pelves.

An interesting case of complete stricture of the lower end of the ureter with a resulting hydronephrosis in a male child a year and a half old is described by Dr. Grünberg (*Munschen med. Wchnschr.*, 1899, xlvi, 748).

Lebec (*Presse méd.,* 1897, ii, 273) reports a similar case in a man of 34, where there had been symptoms for many years, and in which the entire ureter was obliterated.

Abnormal curves of the ureter, met with particularly in ectopic kidneys, as well as valves and strictures in its course, have also been observed in many cases and shown to be the cause of hydronephrosis. Twists and curves are resultant effects of ureteral obstruction more often than they are causative influences (Fig. 252).

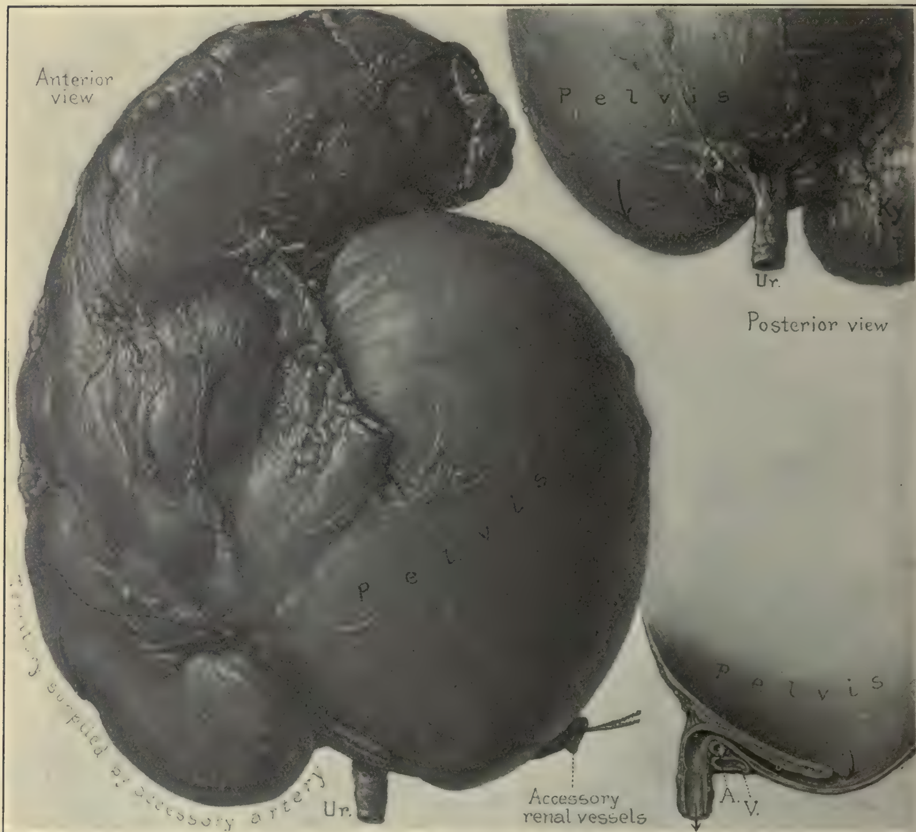


Fig. 253.—Large Hydronephrotic Kidney Due to Descensus and Kinking of the Ureter by Accessory Renal Vessels. These vessels passed in front of ureter near its junction to pelvis, as shown. The territory of kidney supplied by these accessory vessels is indicated in drawing to left. Tying of such a vessel would result in infarction of this part of the kidney, as the circulation is a terminal one. The capacity of removed specimen, 300 c. c. (Case of Dr. Omar Pancoast. E. G., Oct. 6, 1909.)

Interest of recent date has been mostly focussed upon the etiological importance of the so-called supernumerary or abnormal blood vessels. That such vessels can lead to compression of the ureter has been long observed. Legueu (*Ann. des mal. des org. génito-urin.*, 1904, xxii, 1,361) emphasizes their importance and states that cutting the vessels would often cure the condition. Ekehorn (*Arch. f. klin. Chir.*, 1907, lxxxii, 955) has clearly drawn attention to this matter and emphasizes its important practical bearing. Furthermore, it has been particularly illuminated in this country by Dr. Wm. Mayo and a number of cases reported by him are most convincing.

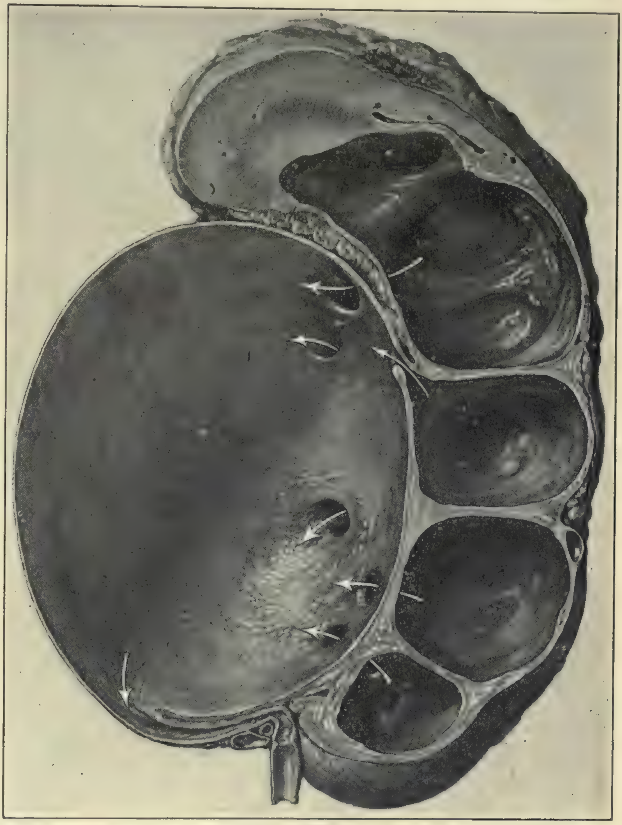


Fig. 254.—Same Kidney as Shown in Last Figure. Note how, in spite of dilatation of pelvis and of calices, the necks of calices have remained comparatively small and contracted.

Bear in mind in this connection that it is easy to confuse cause and effect; that in many of the old and large hydronephroses the vessels are drawn out of place and seem to obstruct the ureter, when in reality they have no such bad effect, but have been drawn into their abnormal position by the distending pelvis. Certainly in most cases it is not merely the condition of supernumerary blood vessels, but the fact that the kidney is abnormally movable, which determines the development of the distention. In Figures 253 and 254 is shown an excellent example of how descensus of the kidney has led to a

kinking of the ureter by the accessory vessels, which in this case pass before the ureter near its junction to the pelvis. With a differently shaped kidney it is quite possible for abnormal posterior vessels to lead to like results, although this is rare. It is our personal impression from observation of a number of hydronephroses that obstruction due to supernumerary blood vessels is a rather rare condition.

Finally, the high insertion of the ureter into the pelvis of the kidney or its oblique insertion has been thought by some to be a common obstruction. This seemingly high insertion is, we believe, more often a result of the downward movements of the kidney and of the gradual development of the distention. It is met with in all cases of large hydronephrosis.

Trauma plays an undeniable rôle; a number of cases are on record where hydronephroses have followed injury to the kidney. Most of such are due to pressure from accumulations of surrounding blood upon the ureter and uretero-pelvic junction. As a result of injury there forms a large hematoma in the perirenal tissue in many cases. Some hydronephroses result from the formation of blood clots in the kidney and their passage through the ureter. These traumatic hydronephroses may arise immediately at the time of injury, or the injury may lead to changes which cause a gradual development of the condition.

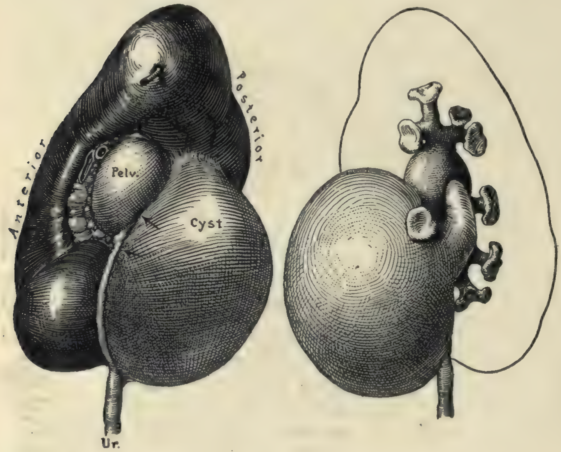


Fig. 255.—Moderate Hydronephrosis Due to Pressure on the Ureter by Cyst in Sinus Renalis. The cyst in this case was thin-walled and filled with clear fluid, and although in most intimate contact with kidney, as shown in drawing to the right, it communicated with neither the parenchyma nor the pelvis. (Autopsy, No. 68, Bay View, Oct. 3, 1908; specimen loaned by Dr. Milton C. Winternitz.)

Compressions of the urethra or obstructions of the flow through the urethra always lead to bilateral hydronephrosis. It is common in cases of prostatic hypertrophy. Probably the commonest cause of bilateral hydronephrosis in the female is cancer of the cervix uteri. Almost

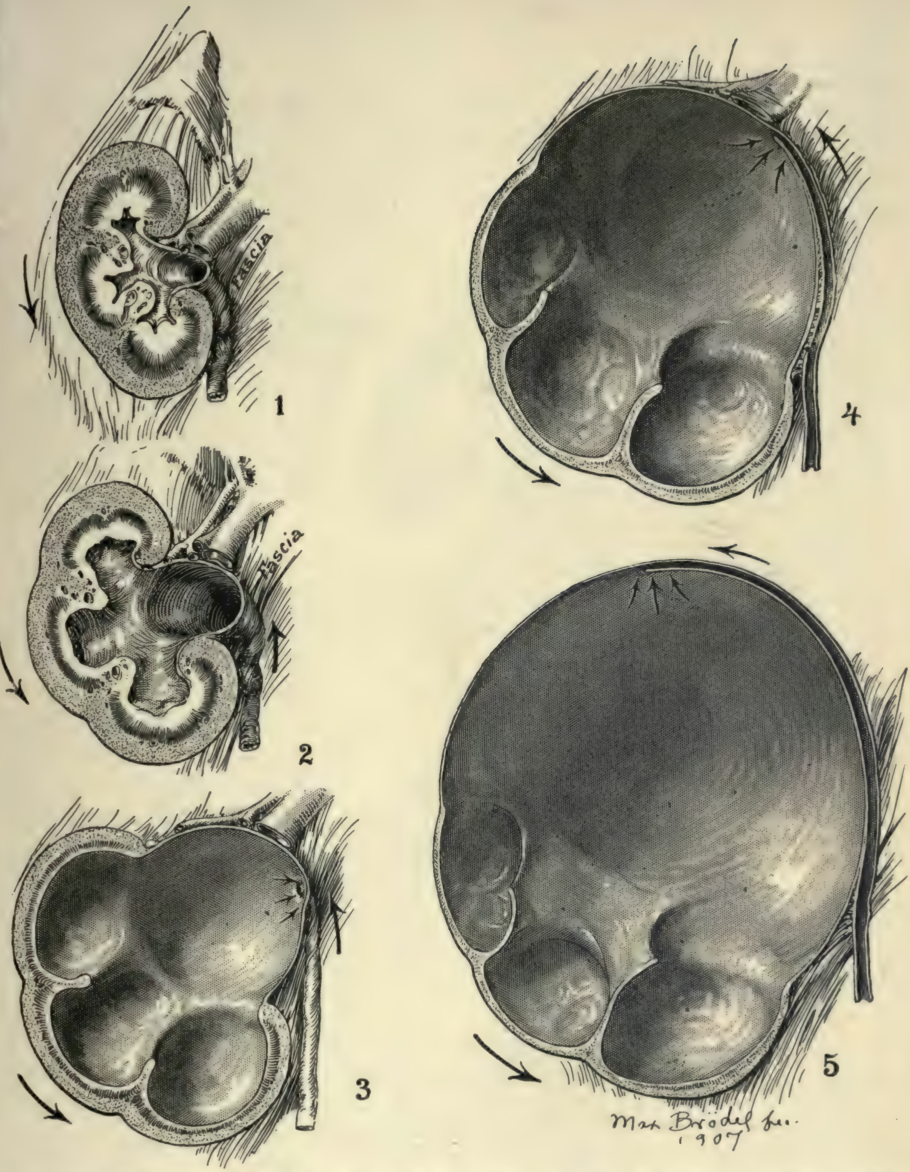


Fig. 256.—Series of Five Drawings from Actual Cases, Showing Transformation of Movable Kidney into Large Hydronephrosis. The kidney not only descends, but swings over toward the middle line, as shown by arrows. The surface of the kidney is the rim, and the attachment of renal vessels to the great vascular trunks the hub of a wheel. This results in a gradual ascent of the uretero-pelvic junction, which causes a kink and valve formation. Once started, the conditions grow automatically worse.

any intrapelvic growth, especially those in the broad ligaments, may lead to compression of the ureter and consequent hydronephrosis. Ahlefelder (*Monatsch. f. Geburt. u. Gyn.,* 1905, xxi, 308) has reported a case where the pressure was due to a pregnant uterus. It seems likely that the pregnant uterus quite often causes slight hydronephroses, but it is rare that they acquire great or even medium size. We have observed moderate hydronephrosis due to the pressure of an adherent appendix, and in another case to that of an adherent ovary upon the pelvic portion of the ureter. Hugh Young has noted attacks of renal colic due to the pressure of inflamed seminal vesicles on the ureters.

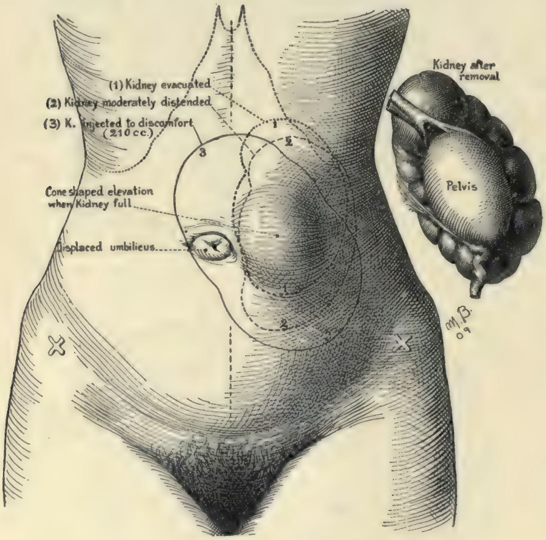


FIG. 257.—POSITION AND SHAPE OF HYDRONEPHROTIC KIDNEY IN VARIOUS STATES OF DISTENTION. The small diagram to the right pictures kidney after its removal. The cone-shaped elevation with fully distended kidney was the pelvis. Note pushing of umbilicus to opposite side of body. (Deardorf, Ch. Home and Inf., May 10, 1907, patient of Dr. G. L. Hunner.)

A rather unique cause is that shown in Figure 255, where a cyst developing in the sinus renalis has pressed upon the ureter and produced hydronephrosis. A similar case, in which an echinococcus cyst in the lower pole of the kidney produced the pressure, has been reported by Tuffier (*Presse méd.,* 1900, viii, suppl., 64).

Among the causes of hydronephrosis from within the ureter or pelvis of the kidney, stone, perhaps, stands first in importance. The association between these conditions is a very common one; a large proportion of stone kidneys show more or less hydronephrosis. These distentions depend either upon the fact that the stone itself obstructs the outflow, or leads to lesions in the ureter which result in obstruction.

Tuberculosis, as well as the pyogenic infections, are also associated in most cases with enlargements of the pelvis and calices. This association is usually dependent upon the fact that these conditions, by inducing a ureteritis, cause strictures of the ureter. It is of interest to note that some of our early tuber-

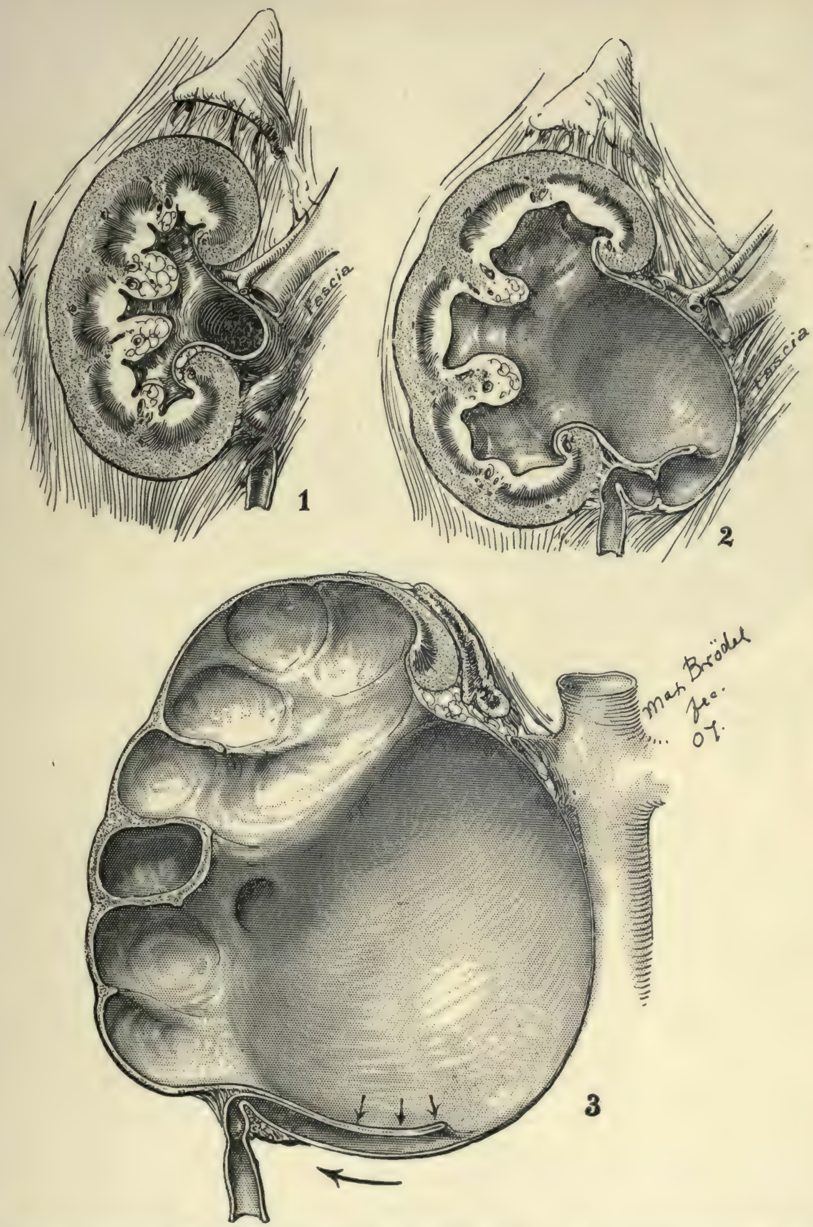


FIG. 258.—TRANSFORMATION OF MOVABLE KIDNEY INTO A HYDRONEPHROSIS. In this case, there is no swing inward, the obstruction being due to the fact that the kidney descends inside its fascial coverings while these remain fixed. The result is shown in 1. In 2 the condition is more advanced and the well-known twisting with valve formation of upper end of ureter is shown. In 3, a still more advanced condition is shown.

cular cases of 20 years ago were diagnosed for some time as stricture of the ureter and pyonephrosis.

New growths of the renal pelvis and of the ureter, as well as of the bladder, may cause obstruction and lead to the distention of the pelvis. Many such cases are on record, but are less frequently met with than the other conditions mentioned.

Fig. 259.—Hydronephrotic Kidney Resulting from Descensus of Kidney with Ureteral Pelvic Junction Caught in Fascia so that Kinking and Partial Valve Formation Resulted. The capacity of this pelvis was 160 c. c.; one-half natural size. (S. H. Age 25. October 9, 1906, J. H. H.)

A b n o r m a l m o v a b i l i t y o f t h e k i d n e y i s u n d o u b t e d l y t h e c o m m o n e s t s i n g l e c a u s e o f h y d r o n e p h r o s i s, a fact now well established on both clinical and experimental evidence. Probably the best demonstration of movability as an etiological factor is afforded by those cases of small or moderate hydronephrosis which are relieved by fixation of the kidney. We have personally had a large group of this class of case. In a series of 64 movable kidneys associated with attacks of colic, no less than 9 showed increasing pelvic capacity on the affected side. The pelves ran, in this series, from 20 to 50 c. c. in capacity (Figs. 256 and 258).

In Figure 256 is shown a series of drawings which illustrate the gradual transformation of a simple, movable kidney into a large hydronephrotic sac. Note how the kidney not only descends, but swings over, toward the middle line, so that the uretero-pelvic junction is pushed higher and higher upward on the pelvis. It is obvious that, once started, the condition forms a veritable vicious circle; that is, the larger the hydronephrosis the higher the insertion of the ureter into the pelvis, and the higher the insertion into the pelvis the more effectual the obstruction and the larger the hydronephrosis.

The position and shape of a hydronephrotic kidney in various states of distention are well illustrated in Figure 257, while in Figure 258 is shown a different, but also very common, mechanism in the formation of a hydronephrosis by movability; here the obstruction arises because the descent of the kidney inside its own fascial coverings results in a kinking of the ureter. The kidney descends, but its pelvis and the uretero-pelvic junction are so held by

fascial coverings that they cannot follow. Note the valve in 3 (Fig. 258). Change in posture relieves the valve of tension and allows outflow of contents by altering direction of gravity.

Cases in which similar causes have brought about a hydronephrosis of 160 c. c. are shown in Figures 259 and 260.

Occasionally both kidneys are affected in this manner, as in an autopsy case illustrated by Figure 261.

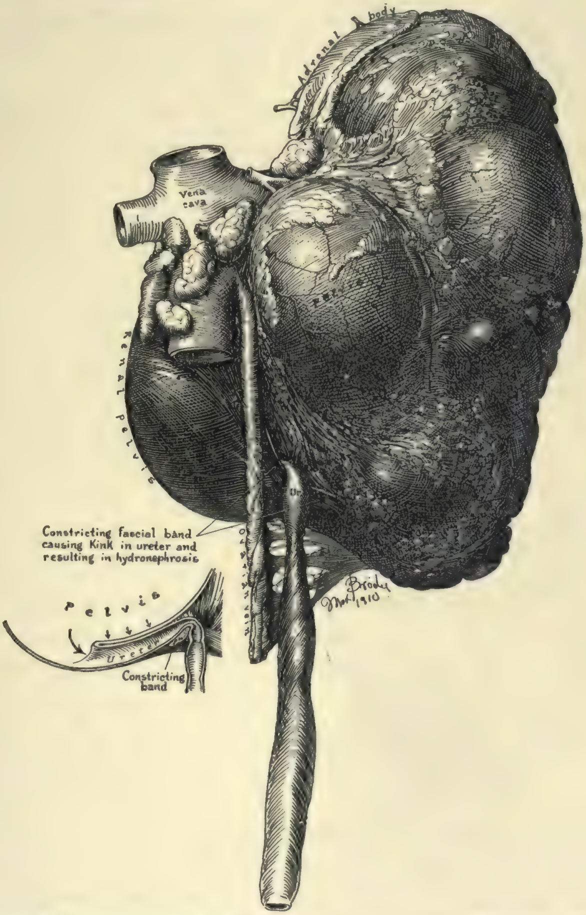


FIG. 260.—LARGE HYDRONEPHROTIC RIGHT KIDNEY SEEN FROM BEHIND. The cause of the condition in this case is twofold: first, descensus; second, a constricting fascial band, part of the renal fascia, which holds the ureter up while the kidney descends and thus forms obstruction through kinking. One-half natural size. (Miss M. P. Age 23, March 30, 1901. Autopsy 1706.)

Where the fascia loops around the ureter it is often found thickened and in veritable bands. We feel that many of the cases of supposed supernumerary blood vessels are really fascial bands.

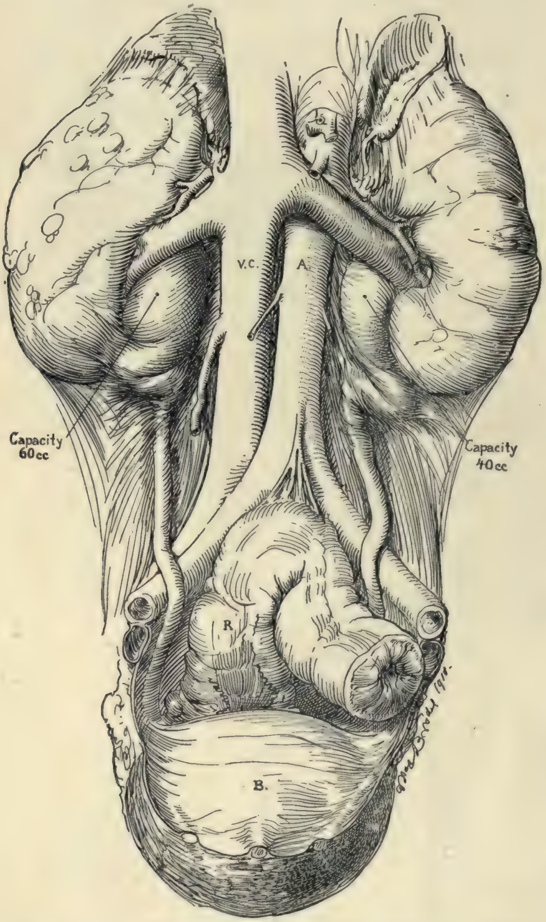


Fig. 261.—Early Bilateral Hydronephrosis Due to Descent of Kidneys in Their Fascia, Producing Kinking of Ureter. (From observation of autopsy, L., Feb. 8, 1901.)

In addition to these latter and abnormal blood vessels, actual pathological adhesions due to a previous perinephritis or pericolitis are not infrequent causes of obstruction to the ureter, provided the kidney is also abnormally movable.

An illustration of the influence of posture upon a hydronephrotic kidney in both distended and empty states is shown in Figure 262, which represents studies from an actual case. The size of the sac was 172 c. c., and the patient showed the long, narrow body so typical of movable kidney subjects.

To summarize, the common feature of all the causes of hydronephrosis is the obstruction invariably present to the outflow of urine from the affected kidney, and the commonest obstruction is that due to abnormal movability of the kidney. It is not, however, movability alone, but an associated condition such as that afforded by bands, blood vessels and adhesions, which determines the formation of the pathological distention.

Some of the causes of hydronephrosis are congenital, others are acquired.

A vast literature has grown up in endeavoring to determine the more frequent. It seems to us that the acquired outnumber those which are congenital. This may, however, be due to the vagaries of personal experience and the character of our clinic.

PATHOLOGICAL ANATOMY.

The appearance of a hydronephrosis varies immensely with the state of distention and the original position and shape of the involved kidney. The volume of the tumor varies all the way from a slightly enlarged normal kidney to enormous sacs holding liters of fluid. In an obstruction at the lower end of the ureter it is the ureter which is first dilated, next the pelvis, then the calices, and finally the tubular system of the parenchyma, up to the glomerulus.

The progressive degenerative changes which occur in the parenchyma of the kidney are shown in the series of studies made by Max Broedel and illustrated in Figure 263. It is evident from this series of studies that the first stage of the disease is due to pressure from within the pelvis, which flattens out the papillary elevation, compressing the ducts, and thus interfering with urinary secretion. Owing to the close proximity of the large drainage veins to the distended calices, the venous outflow is impaired, resulting in an engorgement of the periphery. Sclerotic changes in the arteries accompany this condition. The renal units may remain of normal width, but may also be pulled apart considerably by the stretching of the cortex as shown in V. The peripheral cortex becomes destroyed first, the glomeruli

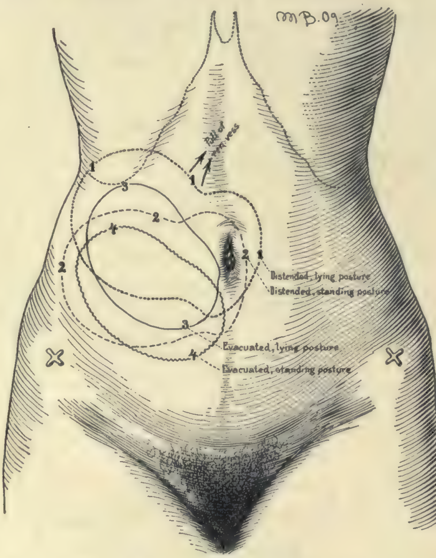


FIG. 262.—A STUDY OF THE INFLUENCE OF POSTURE UPON A HYDRONEPHROTIC KIDNEY IN BOTH THE DISTENDED AND EMPTIED STATES. Actual case. Various positions shown by numbers, and different types of lines. The explanation of higher positions of distended pelvis is the spreading and consequent shortening of vascular pedicle. There is marked descensus in upright as compared with recumbent posture. The total capacity of pelvis in this case was 172 c. c. The body of patient was long and narrow, showing typical movable kidney shape. Becher and Lennhoff index 89.8. (Miss J. P., Ch. Home and Inf., April 24, 1907. Patient of Dr. G. L. Hunner.)

atrophy, the corresponding tubules shrink and disappear. The continuous layer of peripheral atrophic cortex, as shown in II, advances further inward in the later stages as shown in Figures III and IV. This results in the breaking up of the remnant of functionating cortex in the form of islands. The last cortex to withstand the pressure is found in the center of the original renal lobes. In the last stages we meet with a flattening out of the functionating glomeruli which have survived VI′. Owing to excessive pressure from the pelvis, the papillary ducts are partly closed. As a consequence we find greatly dilated tubules in the remnant of functionating cortex.

The earliest change is here manifestly due to pressure within the pelvis, the immediate result of which has been flattening out of the renal papillæ and compression of the contained ducts. At the same time the large drainage veins are pressed upon with resultant chronic passive congestion.

The peripheral glomeruli and tubules suffer first and are the first to disappear. As the peripheral atrophy extends inward, it may break up the functioning cortex into lobules. The last cortex to withstand the pressure is that within the center of the original renal lobe. Note how the tubules and glomeruli are distended. Accompanying the atrophy of the tubular system is a production of scar tissue bringing about a chronic interstitial nephritis. It is quite wonderful how long healthy-looking tubules and glomeruli can persist in a kidney apparently entirely destroyed. Ayrer (*Dtsch. med. Wchnschr.,* 1893, xix, 1108) reports that in 473 specimens he only observed a complete disappearance of kidney tissue in 11. We have observed normal-looking tubules and glomeruli in kidneys which have been out of function for months, and, in some cases, for years.

Large hydronephroses are always open—that is, the obstruction is intermittent. A sudden and complete obstruction of the ureter leads to but little hydronephrosis, which has been shown on human beings as well as on animals. Take, for example, tying the ureter; then the urine is secreted until the pressure reaches at least 73 mm. of mercury, when it stops. If the obstruction is not removed, atrophy of the parenchyma sets in and in the end complete sclerosis. The small amount of fluid accumulated in the pelvis, under such circumstances, is usually absorbed. It is still a question how long such an obstruction can be maintained without permanent injury to the kidney.

We personally know of a case where, during an operation for removal of a cancerous uterus, both ureters were tied, with consequent complete anuria for more than 24 hours. In this case removal of the ligatures was followed by profuse secretion of the urine, and apparently no injury whatever to the function of the kidneys.

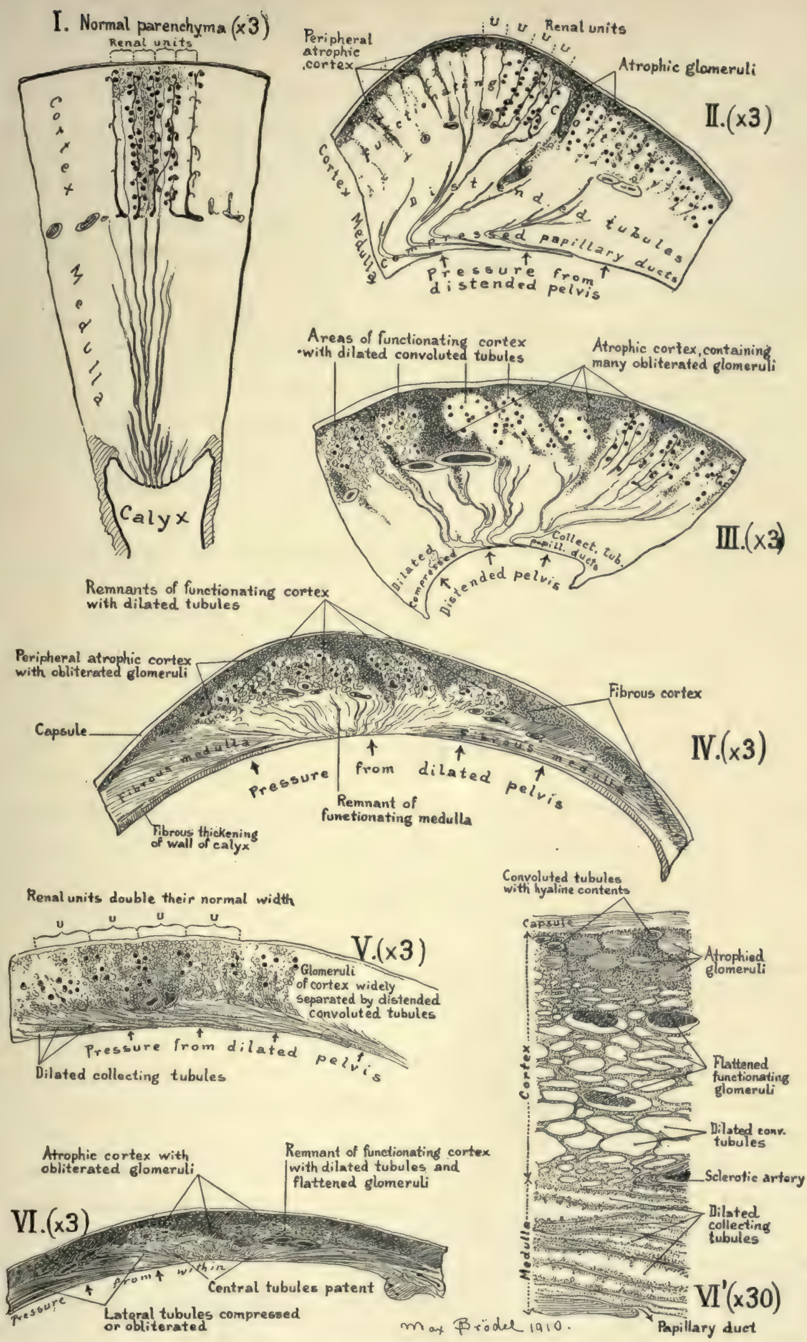


FIG. 263.—PROGRESSIVE CHANGES IN RENAL PARENCHYMA AS FOUND IN HYDRONEPHROSIS.

Donati (*Giorn. d. r. Accad. di med. di Torino,* 1904, x, 597) is inclined to believe, from experimental work on dogs and rabbits, that even a very moderate hydronephrosis, if it has been at all prolonged, is not recovered from completely.

Those hydronephroses which are only intermittently obstructed are spoken of as open hydronephroses. In such cases the growth of the sacs is usually gradual and slow, but in the end they often attain enormous dimensions.

In kidneys with double ureters and pelves, one occasionally meets with partial hydronephrosis, i. e., a hydronephrosis of half of the kidney, the other half remaining normal. Such a condition is amenable to treatment of a different kind from that employed when the hydronephrosis is complete. Rarely a partial hydronephrosis results from an obstruction to one calyx, or to a single papilla. We have observed this condition in one case where the papilla was sealed by a tubercular process.

The opposite kidney in a prolonged hydronephrosis which is one-sided usually shows compensatory hypertrophy. During an attack of colic it may cease to secrete. This is fully as characteristic of the conditions of renal colic when due to hydronephrosis as when due to stones in the kidney.

SYMPTOMS.

The classical and characteristic symptoms of hydronephrosis are pain and tumor, which occur in the form of attacks with varying intervals of health. There are many cases, however, which do not present these symptoms. It is common to find hydronephroses which give no subjective manifestations. This is true whatever may be their cause, but is particularly common in bilateral cases due to retentions in the bladder. In such the first symptom indicating involvement of the kidneys may be uremia. The diagnosis of hydronephrosis under such circumstances is most commonly made on the autopsy table. It is, however, much more frequently arrived at now that the methods of diagnosis by urological examination have become so definite.

The pain due to hydronephrosis, and met with in many cases, usually comes in the form of definite attacks of colic. It presents all the variations in duration, in location, and in radiation that renal colic shows when due to any of its numerous causes. The pain may be in the back or in front, all the way from the costal margin down to the crest of the ileum. Its duration varies from an hour in a short attack to several days in a long one. It may recur

every few weeks, or there may be years of interval between attacks. The intensity of the pain also varies; sometimes it is almost unbearable, and may even cause the sufferer to faint. Accompanying these attacks there are usually marked general symptoms; nausea and vomiting are common, and usually some urgency in voiding. Obstinate constipation and sometimes symptoms of intestinal obstruction are present. Usually the amount of urine secreted by the opposite and healthy kidney is greatly diminished. There are some cases on record where complete suppression of the urine has been noted. Following the attack there is usually marked polyuria. This was formerly supposed to be due to the emptying of the contents of the sac, but is now recognized as a functional polyuria.

Tumor is a valuable manifestation so far as aiding in the diagnosis is concerned. Attacks of renal colic associated with the formation of tumor in the side are characteristic of the condition and distinguish it from stone, essential nephralgia, and other conditions producing pain in attacks. Tumor is manifest only in such cases as attain considerable size. It could never be made out in an early case. It may be either intermittent, as in open, or permanent, as in closed hydronephrosis. There are many cases of tumor due to hydronephrosis in which there is no pain and no history of pain in the side. Such conditions must be carefully distinguished from other cystic tumors of the abdomen. It is not an uncommon thing to have an abdomen opened for an ovarian cyst when the condition is really an immense hydronephrosis. The appearance of such an enormous tumor is shown in Figure 264. The enlarged veins pictured in this case are quite common. As a rule, the percussion from behind gives a dull note, and there is tympany in front, due to the colon. Percussion findings, however, are extremely uncertain, and often do not follow this characteristic type.

The influence of posture on the appearance of a hydronephrotic kidney and also the influence of distention are well shown in Figures 257 and 262.

Occasionally hematuria has been noted in association with hydronephrosis. Such a case was reported by Dr. L. B. Bangs (*Med. News,* N. Y., 1905, lxxxvi, 253).

The symptoms of hydronephrosis are, of course, modified by infection. Here we may have all the manifestations of a pyonephrosis, viz., fever, chills, pain, pus in the urine, etc. Some of the hydronephroses in which there is a sudden and violent onset of infection may look like general peritonitis. However, they are usually readily distinguishable by a careful general examination.

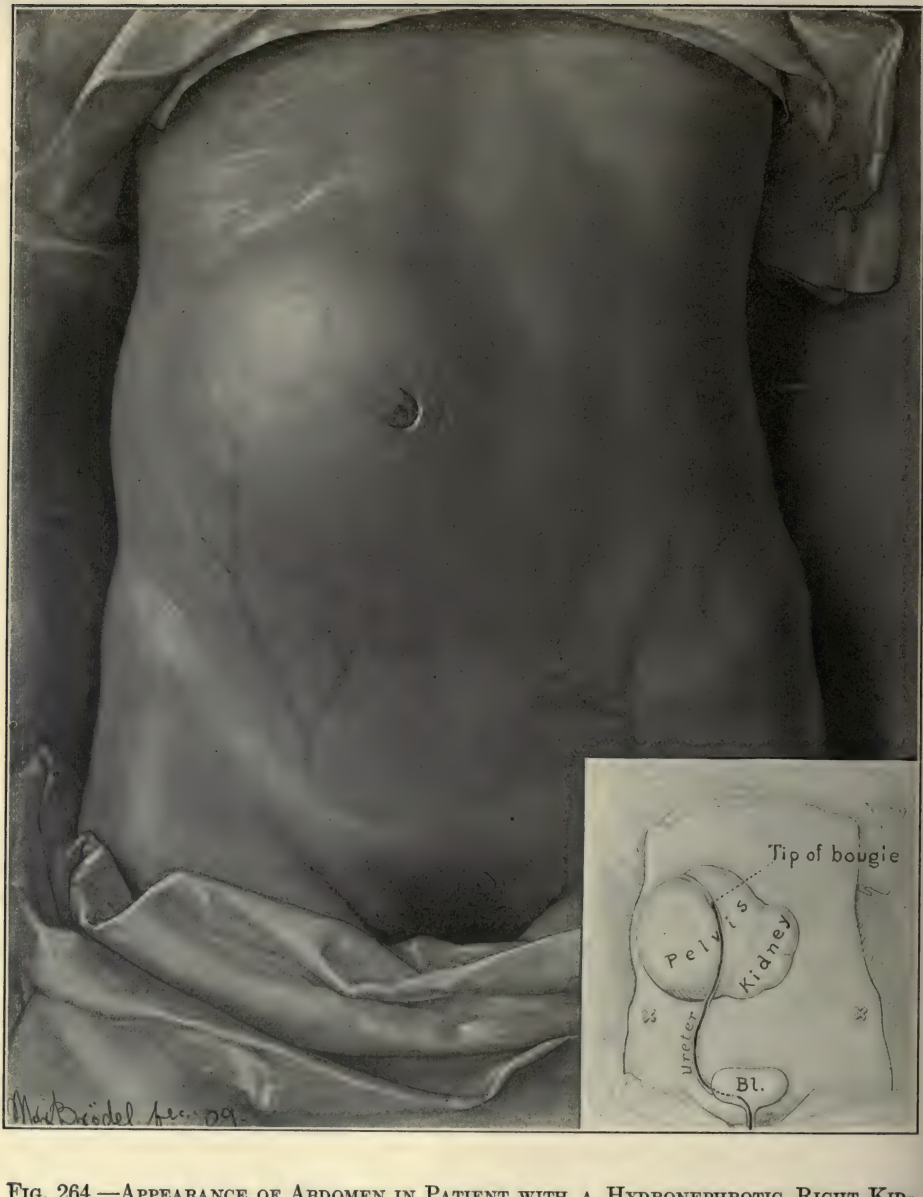


FIG. 264.—APPEARANCE OF ABDOMEN IN PATIENT WITH A HYDRONEPHROTIC RIGHT KIDNEY, HOLDING 1,250 C. C. OF FLUID. Dorsal position. Note prominence of abdominal veins. The small outline drawing in right lower corner shows why the catheter in ureter fails to empty sac. This would probably always be a difficulty in very large hydronephroses, where swinging to middle line and ascension of uretero-pelvic junction exists.

DIAGNOSIS.

Before the introduction of the renal catheter and the cystoscope, the diagnosis of hydronephrosis, in the large cases, was sometimes difficult and nearly always problematic and quite impossible in the early stages of the condition. The presence of a fluctuating tumor in the region of the kidney is suggestive; in fact, it is almost positive evidence of hydronephrosis if it occurs intermittently and is associated with renal colic.

The diagnosis, as at present made, must not only show positively that there is a dilatation of the pelvis of the kidney affected, but it should also show the extent of the dilatation and the conditions of the opposite kidney as far as hydronephrosis is concerned, as well as the functional activity of the affected kidney and its fellow.

To work out these various findings, one must make urinary examinations, use the cystoscope, catheterize the ureters, employ the functional tests, and secure X-ray pictures, especially those after injections of collargol into the pelvis of the kidney.

Urinary Examination.—The urine of hydronephroses is not characteristic. In a closed case the urine coming from a healthy kidney on the opposite side is perfectly normal in every way. In the presence of infection there is the infecting organism and pus. In rare instances blood is found either alone or mixed with pus and other abnormal elements. With a history and general examination findings pointing to hydronephrosis, the most characteristic condition of the urine is normal. Most other conditions, such as stone, tuberculosis, neoplasm, essential hematuria, etc., which can be confused with it, show pathological elements in the urine.

Cystoscopy.—Many hydronephroses are readily recognizable by a cystoscopic examination alone; perhaps the clearest way to illustrate this is by citing the conditions upon which a positive diagnosis can rest.

First, if there is a cystic tumor in the region of the kidney, and inspection of the bladder shows the ureter on that side is not functionating while its fellow is actively secreting, then the evidence of hydronephrosis is conclusive. Equally positive are those cases in which the urine on the hydronephrotic side pours down in a continuous sluggish stream, in marked contrast to the opposite side, where the regular normal rhythmic ejaculations follow each other. This kind of study is greatly facilitated by giving the patient abundant water to drink before the examination and by the injection of from 5 to 20 c. c. of indigo-carmin solution.

Under such conditions, in a case of a large hydronephrosis with consider-

able impairment of kidney function, the observer will make out on the healthy side a blue urine, while on the diseased side it shows pale or colorless, depending upon the amount of impairment of the kidney. If, during the examina-

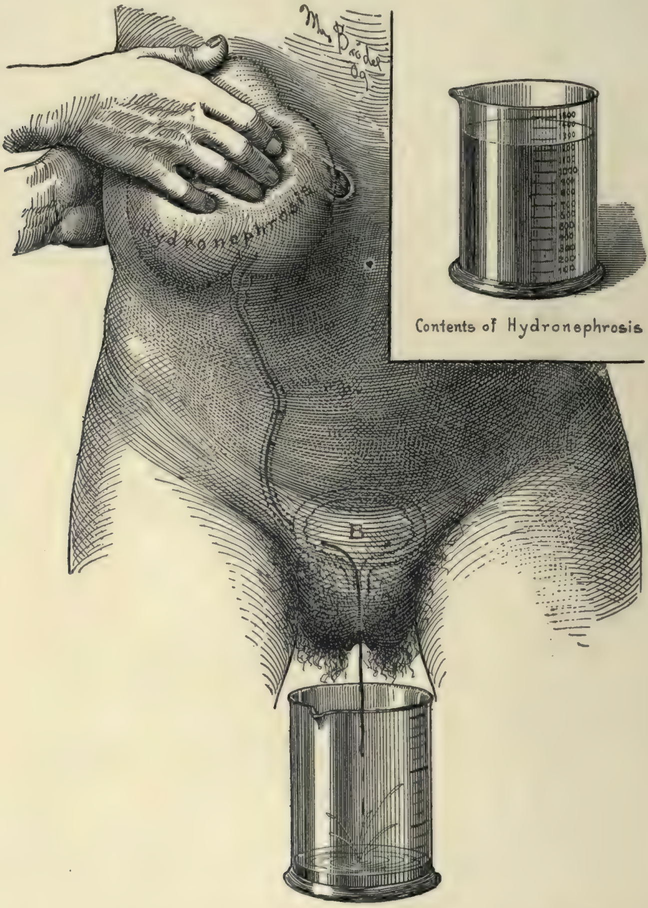


FIG. 265.—EMPTYING OF HYDRONEPHROTIC SAC BY BIMANUAL PRESSURE, WITH RENAL CATHETER IN PLACE. In hydronephroses, even of moderate degree, great acceleration of the flow is often produced by pressure with two hands, as shown.

tion, pressure be brought to bear on the side of the hydronephrosis, it can sometimes be made to empty itself more rapidly. This procedure with the ureter already catheterized is shown in Figure 265.

In early hydronephroses the cystoscopic examination alone not only does

not give a positive diagnosis, but does not even suggest it. Here the next step in the diagnosis, namely, catheterization, which should be carried out in all cases, becomes absolutely imperative.

Catheterization of the Ureters.—Catheterization of the ureters can be carried out by any of the means described in the chapters on Catheterization. It is of great practical help to follow some set plan after the catheterization. When

FIG. 266.—DRAINAGE OF DISTENDED HYDRONEPHROSIS THROUGH RENAL CATHETER AFTER ITS DISTENTION. The posture shown is peculiarly favorable to a complete emptying of the sac.

possible, only large plugging catheters to prevent reflux should be used. The catheter should be introduced all the way into the pelvis. This is, however, not always possible, as is well shown in Figure 264. In such a case the catheter will enter to the point of obstruction and stop there, and no urine will be secured. Such conditions are usually met with only in the large hydronephroses where prominent tumors present on abdominal examination. The passage of a catheter well up into a ureter and the failure to secure urine, with the

FIG. 267. — VERY CONVENIENT SYRINGE FOR INJECTING FLUID THROUGH URETERAL CATHETERS. The tip is conical and fits in any catheter. The capacity of syringe should be 20 c. c. Note two-way stop-cock which makes it possible to fill an empty syringe without removing it from catheter.

certainty that the eye of the catheter and its lumen are open, is, as a rule, in the absence of an abdominal tumor, evidence of other renal conditions than hydronephrosis. When the catheter enters the pelvis, on tapping the hydronephrotic sac there follows a continuous flow of the urine, drop by drop, which should be collected and measured. This continuous dropping is almost pathognomonic of pelvic retention. It is sometimes simulated by a very actively secreting kidney. Complete evacuation of the hydronephrotic sac is often facilitated by having the patient take the posture shown in Figure 266. When the sac is entirely empty, the flow ceases or may become more like that of the healthy kidney on the opposite side, which presents the normal rhythmic spurts. Having emptied the sac, the next step is to distend it. This is conveniently accomplished by the use of the syringe pictured in Figure 267; the use of which is shown in Figure 268. The injection is made with normal salt solution colored with methylene blue, and should be carried to the point of production of pain. The blue color enables the operator to determine whether there is a reflux or not. The exact number of c. c. injected should be noted, the patient should be made to describe the pain, and to state whether it is the same as that she had before. As already pointed out in other sections of this book, we have never yet observed pain due to the kidney which has not been identified by the patient on the injection. Next, the injection is allowed to run back and is measured again. By this procedure the size of the hydronephrosis is accurately determined. In a pelvis of more than 30 c. c. capacity, there is no dispute among observers as to the conditions being hydronephrosis. On the other hand, there has been much discussion in the cases of smaller capacity than 30 c. c. Many authors state that pelves under 30 c. c. are not hydronephrotic, but normal. Under certain conditions one does find normal pelves almost up to 30 c. c. Such are particularly met with in kidneys where the pelvis is largely or entirely extra-renal.

Functional Tests.—As pointed out on page 520 the average normal adult pelvis has a capacity of 7 c. c.

Many normal pelves will hold only 1 or 2 c. c. Considering these facts, it is evident that if the original pelvis contained only 1 c. c. and that the dilatation had brought it up to 20 c. c., such a pelvis is much more hydronephrotic than one which started at 20 c. c. and has been dilated to 40. How is it possible, then, to tell in a pelvis of from 20 to 30 c. c. whether it is in a normal or hydronephrotic state? Provided the condition is due to some obstruction above the bladder, the answer is found by comparing with the size of pelvis in the opposite kidney. We have found in a great number of clinical studies of normal cases

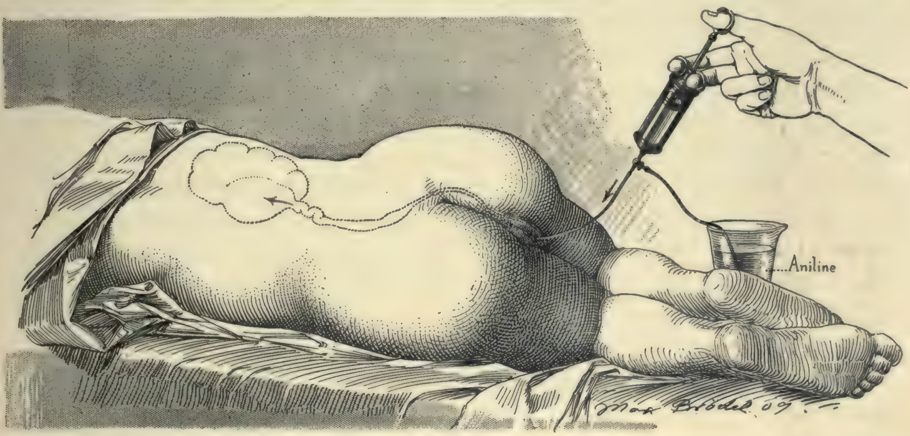


Fig. 268.—Illustration of Using Injection Method to Determine Capacity of Renal Pelvis in a Case of Hydronephrosis. Injection should be carried on to the point of pain.

that the two pelves are approximately equal, rarely varying more than one or two c. c. This clinical finding has been substantiated by the extensive anatomical studies of Max Broedel to such an extent that it can be made an axiom that the pelves of the kidneys in a normal individual are of equal size. Furthermore, in hydronephroses of the early stage it is the rule to find a pelvis which has been dilated, say to 20 c. c., to show less force in its contractions and consequent ejaculations than that which is normally of 20 c. c. capacity. Therefore, the character of the flow through the catheter should also be carefully observed and noted.

Wm. Braasch, of Rochester, Minn., has pointed out that even in early hydronephrosis the calices tend to be more bulbous and less pointed than in the normal pelvis, and that this condition is capable of demonstration by means of X-ray pictures of a collargol injection of the pelvis.

Having determined the size of the hydronephrosis, the next step is to find out what influence the process has had upon the function of the kidney. This is ascertainable by securing the urines from the separated kidneys in a period of at least one hour. The various functional tests mentioned in the chapter devoted to that subject should be employed. As a rule, small hydronephroses are not associated with any deterioration in function. By small, we mean pelves up to 20 c. c. In the larger cases there is a diminution of the function of the hydronephrotic kidneys as compared with their healthy fellows. In the very large and old cases, such kidneys may be practically functionless. It must be kept in mind, however, that the functional test gives nothing but the power of the kidney in the first hour after relief of the obstruction. It does not show how much recuperation can take place. In several cases where we have left the catheter in for many hours we have observed a distinct improvement in the hour periods. Left in for days, or months, the recovery is probably still more striking. This, however, is merely speculative and cannot be carried out in practical work. We regard urea as the best single substance to indicate the relative value of the two kidneys. It should, however, not be relied on alone, but a complete comparison by the various tests made.

X-ray Examination.—Finally, excellent ideas as to the size and condition, and, in some cases, cause, of the hydronephrosis can be secured by X-ray pictures after collargol injections into the kidney. By those who have convenient and readily accessible X-ray apparatus this method should not be neglected. As a rule, for comparison, it is well to inject the opposite kidney at the same time. By such shadow pictures very striking results are obtainable and the diagnosis completed.

PROGNOSIS.

The outlook, of course, is better when the disease is unilateral. Some such cases persist for many years without serious impairment to the general health. The disease is progressive, however, and sooner or later leads to dire consequences. When the condition is bilateral the commonest end is by uremia. Many of the unilateral cases finally become infected and threaten life through this complication.

TREATMENT.

The remarkable recent advance in diagnosing hydronephrosis is fully paralleled by the progress made in its successful treatment.

The first rule to follow in deciding on the therapy of hydronephrosis is: Every case of hydronephrosis without exception demands active treatment. The reasons for this are apparent by a consideration of the course which the disease takes. This has already been fully stated, but for the sake of emphasis we here repeat the principal facts of the disease having bearing on the treatment, a clear understanding of them being indispensable to a comprehension of what follows: They may be placed under three heads:

First, hydronephrosis is a progressive process, leading in the end to destruction of the involved kidney. During its development it may occasion such pain, with pressure effects, as to seriously impair the general health.

Second, it furnishes a typical focus of diminished resistance to infection, and, in most cases, sooner or later, the comparatively harmless hydronephrosis becomes a pyonephrosis which in a few days or weeks may reduce a healthy person to the point of death, and almost always destroys the kidney.

Third, the reasons for early operation lie in what has already been said, for, when taken early the patient can not only be relieved of pain, discomfort, and the dangers of infection, but can likewise be secured a sound, healthy kidney, an end of such vital importance as to need no defense.

The treatment to be followed in the individual case depends in general upon the stage the process has reached when first discovered, and in particular on the nature and location of its cause, which is invariably an obstruction to the free outflow of the urine. This obstruction may be situated at the junction of the renal pelvis and the ureter, at the end of the external urethra or at any point in the urinary tract between these two locations. Therefore, the ideal treatment is casual; it permanently removes the obstruction wherever situated and so allows a free outflow to the urine. We must know, however, in each case whether the secreting power of the kidney justifies the opening of the excretory channels. From the experimental work of Donati, as well as from many clinical observations, we are convinced that a kidney which has been impaired by distention resulting in hydronephrosis does not return to its original condition, even when the cause of the hydronephrosis no longer exists; on the other hand, the destructive process is held up, a slightly crippled kidney being far preferable to none at all.

Another view stands out: If, when examined, it is evident that the kidney is entirely destroyed or very nearly so, then efforts to preserve it are wasted and useless. The indications for treatment in such cases are pain and danger of infection; one resorts, therefore, to simple removal of the hydronephrotic sac rather than to more difficult and uncertain procedures. Still another standpoint of treatment is afforded where a physician is called in to

treat an acute attack of hydronephrosis. Here immediate operation is usually out of the question, and some means must be found to relieve promptly and safely the pain and other symptoms. At this point it should be stated that OPERATION ALONE WILL SECURE COMPLETE AND PERFECT RELIEF OF THE CONDITION. Thus our methods of treatment according to the indications fall readily into three great groups:

First, palliative measures, aiming to relieve immediate dangers and discomforts.

Second, radical operations, permanently relieving pains and discomforts, but sacrificing the kidney.

Third, ideal conservative operations, relieving pains and discomforts and saving the kidney by removing the obstruction.

Now, consider these in detail in the order given.

First, Palliative Measures, Aiming to Relieve Immediate Danger and Discomfort.—These mean putting the patient to bed; giving morphia; altering the position of the bed or the posture of the patient; manipulative procedures; catheterization of the kidney through the bladder; and aspiration of the sac through the side.

A patient found suffering from an acute attack of hydronephrosis, whether we are dealing with an advanced case or with one in the very earliest stage, as is sometimes found in movable kidney, should be put to bed and given morphia in doses of $\frac{1}{4}$ gr. hypodermically. In many cases this alone suffices to relieve the pain. Often some simple device, such as raising the foot of the bed, or putting the patient on one side, or, if that is not successful, putting him on the other side, will effect a relief from the attack. Of course all attacks of acute colic in the hydronephroses are of the intermittent type. Another method especially valuable in cases of hydronephroses of small to moderate size due to movable kidney is manipulative procedures, which may be of distinct advantage. Methods of this kind have been practiced by Küster, Roberts, Broadbent, and Edebohls. Henry Morris, in his "Surgical Diseases of the Kidney and the Ureter," 1901, 1, 432, mentions a case reported by Mr. Thurnam in 1837. "A four-months-old boy had a lobulated tumor in the side which his mother was in the habit of rubbing with her hand to relieve the pain; while doing this she noticed the child's bladder swelled up as large as an egg. There is absolutely no harm in trying such methods provided they be carried out gently."

Dr. George Edebohls was one of the first to employ manipulative procedures to reduce hydronephroses, and apparently met with considerable success.

Catheterization of the Ureters.—During an attack of hydronephrosis it is sometimes possible to give the patient immediate relief by the passage of a renal catheter through the bladder, up the ureter, and into the sac. We have frequently succeeded by this means in bringing instantaneous relief to the patient. As is already pointed out, and as is shown in Figure 264, such a maneuver is not always possible. Occasionally cases are met with where fluid can be injected into the pelvis of the kidney with the catheter, but will not run back. We should be most careful for this reason in injecting hydronephroses, as occasionally severe attacks of pain may be brought on by a simple injection. In Figure 266 is illustrated the method of drainage of the sac by means of the renal catheter. Note the importance of securing a favorable posture in order to completely empty the sac. Occasionally the catheterization of the ureter does more than temporarily relieve. It may permanently cure the condition. Alsberg reported at the meeting of the German Society for Surgery, 1892, a case of hydronephrosis where the sac had been opened in the lumbar region with a consequent permanent fistula, which he succeeded in relieving by retrograde catheterization from the kidney to the bladder.

Albarran and Imber also have reported several successes of this kind. It is of advantage in some cases to leave the catheter in for several days. When the kidney is practically destroyed, catheterization may give so much relief that the patient will permanently stop coming to the doctor.

Aspiration of the hydronephrotic sac through the flank is a method which was formerly employed in many large hydronephroses instead of operation. This method is unsurgical and results in but few cures, although such are on record (Henry Morris, "Surgical Diseases of the Kidney and Ureter," 1901, 1, 432). Cases have also been recorded by Tuffier. This puncture method would seem to give hope of cure in cases where the obstruction causing the hydronephrosis is of a temporary nature, such as is so often the case after injury and the blocking of a ureter by blood clot. In many of such cases it is impossible to catheterize the kidney through the bladder.

In case a puncture is decided on, it should be carried out as follows: The patient's skin should be prepared as for a surgical operation; a large needle or a small trocar should be used. The point of puncture should be always extraperitoneal and always outside the colon. The position of the colon can be readily determined by first dilating it with air and then percussing it out. Usually a safe point for aspiration is through the superior lumbar triangle, from which so many of our incisions start. Such an aspiration may give relief at once to almost unbearable pain and does away with symptoms and the dangers of a reflex anuria.

So far the treatments which we have advised have been toward the relief of an acute hydronephrosis. We have mentioned already that in certain rare cases permanent cures may result from the method which we have described. By certain conservative and non-operative procedures the physician has it in his power to postpone, and occasionally to indefinitely postpone recurrences of similar attacks. We refer here to the employment of bandages. When a hydronephrosis is of moderate size and due to movable kidney, a bandage may suffice to keep the kidney in place and thus relieve the situation. Such a measure is not so effective as operative suspension of the kidney, and we do not advise its use for obvious reasons.

The bandage, in treating hydronephrosis, while not quite so successful, can be fairly compared to the truss in the treatment of hernia. In some cases it is effectual and does not bother the patient, but may give permanent relief.

Second, Radical Operations, Permanently Relieving Pains and Discomforts, but Sacrificing the Kidney.—As the name suggests, the operations of this group should be applied to cases where the kidney is entirely destroyed. No effort is directed to remove the cause of the hydronephrosis, but the hydronephrotic sac itself is destroyed by extirpation. Therefore, this kind of treatment is, for the most part, concerned with large hydronephroses; with those which are badly infected; and with those where ureteral catheterization and functional diagnosis have demonstrated that the kidney has been almost or entirely destroyed. It also presupposes, in most cases at least, the other kidney to be sound, a fact readily determined by ureteral catheterization and separate studies of the urine from each kidney.

Technique of Operation.—After suitable preliminary preparation, the patient is placed on an Edebohls kidney bag. Then a posterior or a posterior-lateral incision is made through the abdominal wall, care being taken to carefully check all bleeding points. By this means one is carried down to the sac. It often resembles an intestine and must be differentiated. As a rule, it is not wise to attempt to deliver the entire kidney. Such a procedure almost inevitably leads to rupture of the sac. One should deliberately empty the sac on reaching it. After emptying, it can, in many cases, be pulled up and separated from its fatty capsule and from the peritoneum and colon. It is really remarkable in some cases how easily the entire kidney thus peels out. In other cases, especially where infection has taken place, this method may be almost impossible of application. Here we advise the intra-capsular nephrectomy method described for pyonephrosis. After freeing the sac down to the pedicle, this is caught and tied off with strong catgut sutures. The ureter is

easily burned through. This incision is closed almost entirely and drained by a small iodoform gauze pack, which should remain in two or three days.

Before leaving the question of nephrectomy and hydronephrosis, we deem it necessary to state that the nephrectomy should nearly always be by the lumbar route and always extraperitoneal, since this involves so much less danger

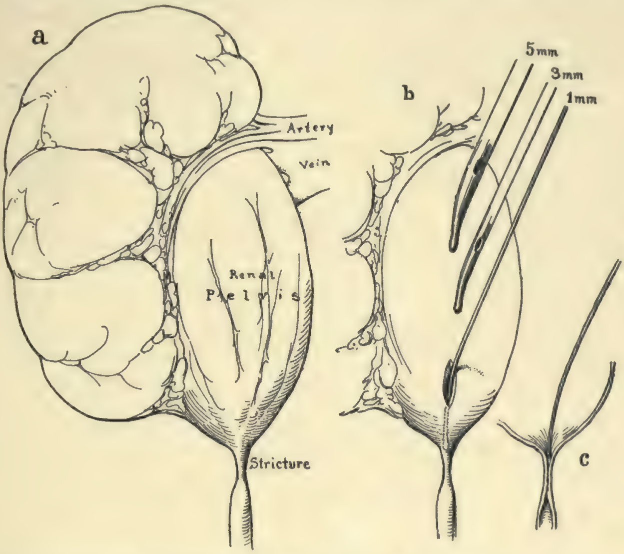


Fig. 269.—Dilatation of Stricture of Ureter at Its Kidney End through Small Opening Made in Renal Pelvis. This procedure was employed with complete success in the case of Mr. W. (No. 960, June, 1900.) He has remained for ten years perfectly well.

to the patient and yields better results. With a sound kidney on the opposite side and with infection in the hydronephrotic sac, nephrectomy is the operation of choice in every way.

During the early years of operative treatment of large hydronephroses there was much discussion as to the relative merits of nephrectomy and nephrotomy; the superiority of the latter method, so far as mortality is concerned, being more than offset by its failure to yield cures. Such patients almost invariably had permanent urinary fistulæ. When it is impossible to locate the cause of the hydronephrosis, even at operation, and a solitary kidney is being dealt with, or both kidneys are involved, nephrotomy has to be done. It gives temporary relief, but very few of these patients survive long after the operation, if the obstruction to the outflow of the urine through the ureter is not

removed. There are a few nephrotomies on record where there has been, apparently, permanent cure. Most of such cases date from the early period of operations of this kind, and doubtless simply mean that the kidney did not refill; they do not indicate that it resumed its function.

Third, Ideal Conservative Operations, Relieving Pains and Discomforts and Saving the Kidney.—The aim of the third group of operations is not only to relieve the hydronephrosis, but also to save the kidney. They possess the common feature of removing the actual cause of the hydronephrosis, which is an obstruction. If the reader considers the multiplicity of etiological factors, he readily appreciates the variety of operative procedures which may be demanded to attain such a result.

The first and simplest operation is suspension of a movable kidney so as to secure an open ureter and thorough drainage of the renal pelvis. This operation is, of course, limited to cases where the cause of the hydronephrosis is abnormal movability of the kidney. It is particularly adapted to the early cases with pelves of smaller capacity than 60 c. c. It should always be controlled by a catheter put in place before the operation has begun. It is often advantageously combined with the separation of adhesions and fascial bands, such as are shown in Figure 258. In some rare cases the suspension may be aided by cutting and ligating accessory blood vessels, such as shown in Figure 253. Suspension of the kidney is not at all applicable to immense sacs or to those where there is a great deal of adhesion about the uretero-pelvic junction. On the other hand, it is a most valuable adjunct, and all that is necessary in a very large group of early hydronephroses due to the sagging down of the kidney. The method is not appreciated to its full value. It must always, as stated, be controlled by a thorough examination of the ureter and pelvis of the affected kidney.

Second, if the hydronephrosis is bilateral and due to some obstruction in the urethra, such obstruction must be removed. Likewise, if the hindrance is found in the bladder, as in papilloma over the ureteral orifice, the treatment consists in extirpation of the neoplasm.

Third, the hydronephroses associated with stone are relieved by removing the stone. In such case the X-ray gives the location and cause of the trouble.

Fourth, occasionally, strictures of the ureter are the cause of hydronephroses. Some of these cases can be relieved by dilatation of the stricture. This can be fairly easily accomplished by means of the cystoscope and graded catheter, when the obstruction is at the vesical end of the ureter. In some cases it is of advantage to leave in a retention catheter. This is always, however, a rather serious thing to do, as sooner or later it leads almost certainly to infection of

the hydronephrosis, and consequently a worse condition than that being treated. Occasionally it is of advantage to treat a stricture of the upper end of the ureter by operating and dilating from the pelvis downward. This form of treatment was followed in the case illustrated in Figure 269. The patient here had long suffered with attacks of renal colic and presented a stricture at the upper end of the ureter and dilated pelvis above. Through a small opening in the pelvis the ureter was thoroughly dilated, and he lived for ten years without recurrence of symptoms.

Fifth, when the hydronephrosis is due to some tumor or mass outside of the ureter, such as a uterine fibroid, ovarian tumor, or pelvic inflammatory disease, the treatment should be directed toward the removal of these pathological conditions.

Sixth, the division of any bands or vessels which obstruct the ureter. This has already been spoken of under heading 1. It is always perfectly proper to cut bands, but in cutting the vessel one should bear in mind that the part of the kidney supplied will atrophy. If the vessel is small it is usually safe to do this. On the other hand, when the vessel is a large one and is, as in some instances, the principal vessel of the kidney, such a procedure is contraindicated. Then the proper treatment is a section of the ureter. After cutting the ureter, the inferior end may be anastomosed into the renal pelvis. A method of this kind which allows the sparing of the part of the kidney supplied by the aberrant vessels is shown in Figure 270. The variety of procedures of this kind which may be carried out is large. In such cases very careful suturing with fine

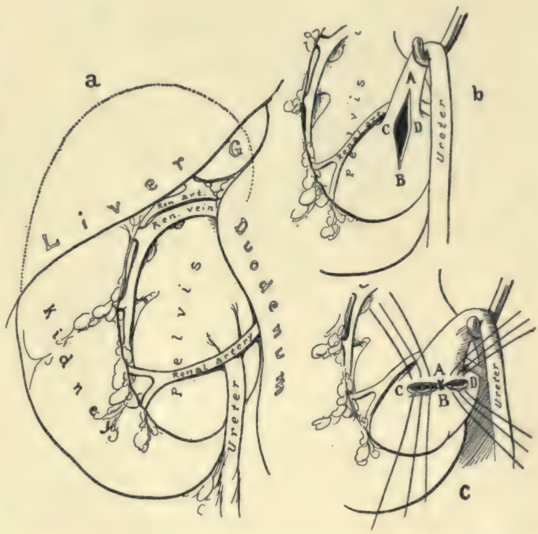


Fig. 270.—Plastic Operation on Uretero-Pelvic Junction to Relieve Hydronephrosis. In this case, the obstruction is due to a renal artery, plus the descensus, as shown in a. In b, the position, extent and direction of incision are shown. In placing the sutures, the points a and b are brought together, thus making the longitudinal slit a transverse one. In this procedure, the renal parenchyma supplied by supernumerary artery is spared.

catgut is indispensable, and a retention catheter should always be put through the ureter into the pelvis and allowed to remain for some days. It can be kept clean by repeated irrigations with 1 to 1,000 formalin solution.

Seventh, various plastic operations on the renal end of the ureter. These operations may be done either from the outside or from the inside of the pelvis. A few types of these operations are illustrated in Figures 270, 271, and

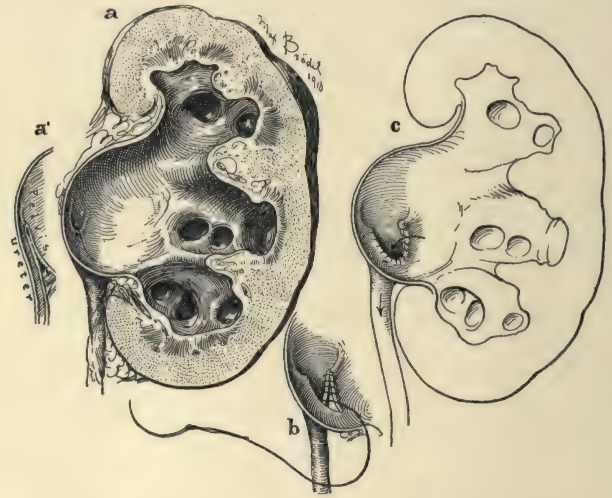


Fig. 271.—Plastic Operation on Uretero-pelvic Junction, Carried Out from Inside of Pelvis. a′ shows the nature of obstruction; a shows the incision removing obstruction; b, the suturing of edges of incision; and c, the completed result. Note large size and dependent position of new orifice.

272. In such cases all the suturing must be extremely carefully done, and the catheter always be left in to secure drainage during the period of healing.

Eighth, plication of the renal pelvis is an operation which is occasionally indicated, and in several cases Kelly has had excellent results. Two were reported in the *Johns Hopkins Hospital Bulletin,* 1906, xvii, 173. The principle of this operation is to take up the baggy part of the pelvis which hangs below the uretero-pelvic junction. The procedure carried out in the two cases mentioned is shown in Figures 273 and 274. Briefly stated, the kidney is exposed and brought into view through a lumbar incision. The large flaccid pelvis with its thickened wall is plicated by silk sutures which gather up the entire pelvis in a V-shape. Each suture starts by transfixing the margin of the kidney surrounding the pelvis and is then carried down into the pelvis

toward the ureteral orifice. It should not penetrate the mucosa, but be carried down into the fascia of the pelvis and then up the opposite side to the kidney margin again. The tying of the three sutures shown in the figure contracted the pelvis down to normal size. It is of advantage in such cases to suspend the kidney, and in both cases illustrated this was carried out.

Ninth, resection of a partial hydronephrosis such as is found when the pel-

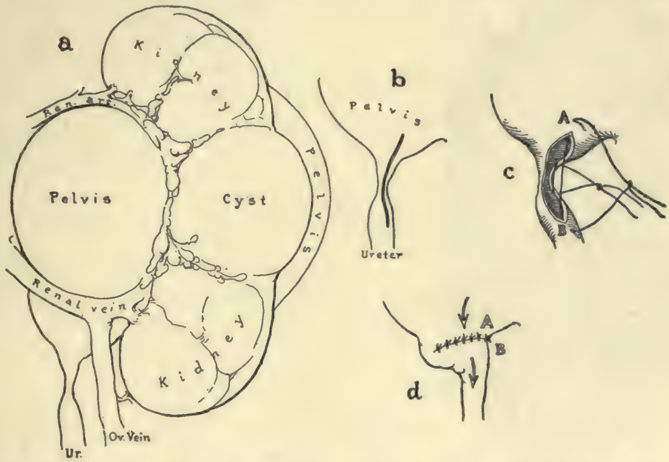


FIG. 272.—PLASTIC OPERATION TO RELIEVE STRICTURE OF URETER NEAR RENAL PELVIS. a shows condition of the kidney; b shows position, direction and extent of incision, which starts in pelvis, extends through stricture down into normal ureter. c shows placing of sutures; d, the completed operation. This procedure recalls the pyloroplasty of Finney.

vis, whether single or double, is hydronephrotic. In such a case the diseased half of the kidney can be extirpated and the healthy kidney left in place. This operation is particularly indicated when the kidney is a solitary one, the commonest type of which is the horseshoe kidney.

Tenth, a number of cases are on record where in large hydronephroses of misplaced kidneys anastomosis has been made between the pelvis of the kidney and the bladder, the two walls being contiguous.

We have already indicated roughly the type of cases to which these various procedures should be applied. In view of the extreme importance of an early recognition of the disease and its prompt treatment, the name hydronephrosis ought henceforth be associated in the minds of surgeons more particularly with the smaller kidneys, and not with those large sacculated organs which represent the end stages of the process.

As already indicated, in early cases a removal of the cause is not only followed by a recovery from the unpleasant symptoms, but is also followed by the cessation of the deterioration of the kidney, and in some cases by improvement of the organ.

The question is asked, what is an early hydronephrosis? It is, roughly speaking, any kidney whose pelvis is smaller than 100 c. c. Such a mechanical division, however, is somewhat arbitrary and does not constitute a sufficient answer, for it is certain that with some kidneys a pelvis of 100 c. c. may be associated with complete atrophy of the parenchyma. This is especially true of cases which have been long completely closed. On the other hand, it is possible for a considerably larger pelvis to be found where the kidney is still actively secreting. A great deal, therefore, will depend upon a thorough study of the function of the kidney by the various clinical methods which we use for such examinations. It is possible for a patient to have but a single kidney, and for that to be quite hydronephrotic, and yet to live for a number of years. One of the patients on whom a nephrectomy had to be done on one side had an infecting hydronephrosis of the opposite kidney, which was greatly improved by renal lavage. She was a very active woman, carried out extensive social duties, and lived for several years in comparative health. In such a case it is evident that every effort should be made to preserve the kidney. A contraindication to saving a kidney, provided the other one is not in good condition, is the presence of infection. In very early and small hydronephrosis suspension of the kidney combined with irrigation of the pelvis may yield excellent results. If the hydronephrosis is large, or if the infection is extensive, such a result is rarely obtained, and when the other kidney is healthy it is a much better procedure to remove the hydronephrotic organ.

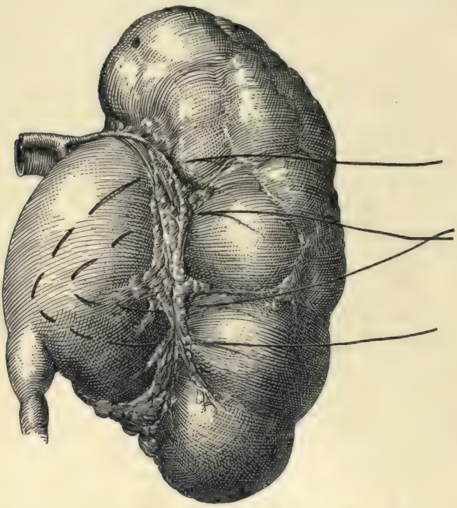


Fig. 273.—First Method of Plication of Renal Pelvis for Hydronephrosis. (C., Dec. 10, 1905. No. 2134.)

In early hydronephroses, as already stated on page 544, there is little impairment of the kidney function. In such cases a suspension is followed by

a perfect return of function and a contraction of the pelvis to normal size. We have observed this in several cases. It is, however, not clearly known whether in hydronephroses which have persisted for a long time there is any restoration of function. Donati, from his experience with dogs (*loc. cit.*), concludes that there is none. It must be borne in mind, however, that there is a great gain if a kidney is saved.

With increased efficiency in the determination of renal function and improved methods of operation, there should be much greater success in plastic operations for the relief of hydronephrosis than has been afforded by the ex-

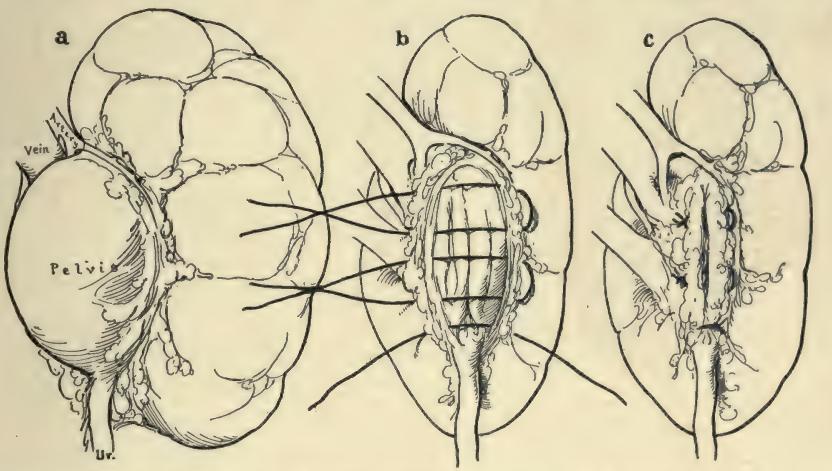


FIG. 274.—PLICATION OF RENAL PELVIS, SECOND METHOD. The sutures catch the renal fascia just beyond edges of hilum. (Mrs. P., May 13, 1905. No. 1927.)

periences of the past. There are but few cases, comparatively, on record. Trendelenburg made an unsuccessful attempt in 1886. Küster was successful in one case in 1891. Fenger (*Arch. f. klin. Chir.,* 1900, lxii, 524) collected and reported 30 operations. In 9 of these there was transpelvic removal through incision of the uretero-pelvic spur, with 5 successes; in 6 reimplantations of the ureter to the most dependent part of the sac there were 3 successes; and out of 11 plastic operations at the site of stricture 10 were successful. Schloffer (*Wien. klin. Wchnschr.,* 1906, xix, 1515) brought the number of cases up to 86. Wagner (*Folia Urologica,* 1905, i, 125) collected all the cases up to the time of his publication. It is to be hoped that surgeons everywhere will report in full the functional results obtained before and after such operations.

In most of the cases in which these operations have been done there has been no careful study of the renal function before or after operation. There is a pressing need that every such case operated on be most carefully studied in the future, in order that we may determine just what results follow these conservative procedures. There is also room for experimental work on animals to elucidate this same question. It is not too well to accept the conclusions of Donati without further confirmation.

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